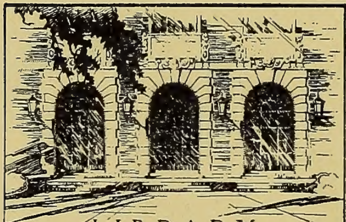


Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - MATHEMATICAL METHODS

PART III - SWITCHING CIRCUIT THEORY

PART IV - ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

January 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The Rich Electronic Computer Center at Georgia Institute of Technology is participating in this work by the support of a staff member at the University of Illinois.

1. Shifting Register Test Unit

When the unit stopped on December 31, 1958 after a run of 387.8 hours, the number of shifts was off by 4. This error, which proved to be intermittent, was finally traced to a transistor with low $V_{cb\ rev}$ and $V_{eb\ rev}$ in the shift counter. In the course of testing, several points were found to be probe-sensitive. Seven diodes with out-of-range characteristics, one unsoldered connection, and one transistor with low $V_{cb\ rev}$ and low $V_{eb\ rev}$ were found.

New power cables with heavier wires were installed to minimize the number of plug connections and to reduce the voltage drops in the cables, thus equalizing the voltages applied to the three separate sections of the unit. It was found that the lower resistance of the new cable caused the noise on the buses to be substantially higher than with the old arrangement because of reduced decoupling. 500 μf bypass capacitors were required on the -4v, +25v, and -25v buses to reduce the noise to the previous levels.

At that time, the unit still failed to work reliably. A "blip" on one of the shift counter outputs led to the discovery of a transistor with very low $V_{cb\ rev}$ and $V_{eb\ rev}$. A diode with erratic characteristics was also found. After an initial error caused by a failure of the fan to cool the unit sufficiently, the unit made no further error for 199.0 hours. Again the number of shifts was off by 4. No cause could be found. When restarted the unit ran successfully. It was stopped after 88.4 hours because the shift time had increased from 235 to 280 mμsec and because two gate signals had deteriorated. These conditions were traced to a transistor

with erratic α and to a shorted diode.

At that point another endurance run was started. At noon on February 1, 1959, the unit has run successfully for 288.0 hours, and was continuing to run during early February.

(G. A. Metze)

2. Basic Circuits

As was reported before, so called push-pull gating can speed up the transfer of information during shifting because only one 0-1-0 sequence is necessary for an up-and-down shift. Over the last few weeks a complete stage of a push-pull gating register was designed and built and the associated drivers analyzed. It turned out that the best way of insuring exact phase-opposition of the two driver outputs (one going into the upper ANDs and the lower ORs, the other one into the upper ORs and the lower ANDs — each Schmitt trigger flipflop being set by an AND and an OR via two diodes) is to build the power stages as a difference amplifier.

The feasibility of constructing one complete base 4 adder stage with all the input and output gates (see also December Technical Progress Report) with no collector delays was further investigated. It was shown that the guaranteed minimum output swing of restoring elements has to be raised to 2.5v and that the flipflops of the Eccles-Jordan or Schmitt trigger type have to be replaced by F-elements. The 2 wire logic circuits were modified accordingly; v_{eb} reverse is now required to be better than 3.2v at 100 μa. In this system use is made of multiple input F-elements. This new development allows the addition of supplementary input paths with only 3 transistors per path as contrasted with 4 transistors for gating to either Schmitt triggers or Eccles-Jordan flipflops. Furthermore, the input sensitivity is 0.6v instead of the 1.2v usually required at the AND (or OR) input which sets the flip-flop via a diode.

The use of F-elements makes push-pull gating particularly easy and eliminates problems which occur when the transmission of information is to be inhibited in all directions simultaneously (all AND inputs = 0, all OR inputs = 1 in the Schmitt trigger system). A driver, shown schematically in Figure 1, which is a series of difference amplifiers with base-selection, solves the whole transfer problem. The idea is simply to connect, for example, the up-driver as a difference amplifier

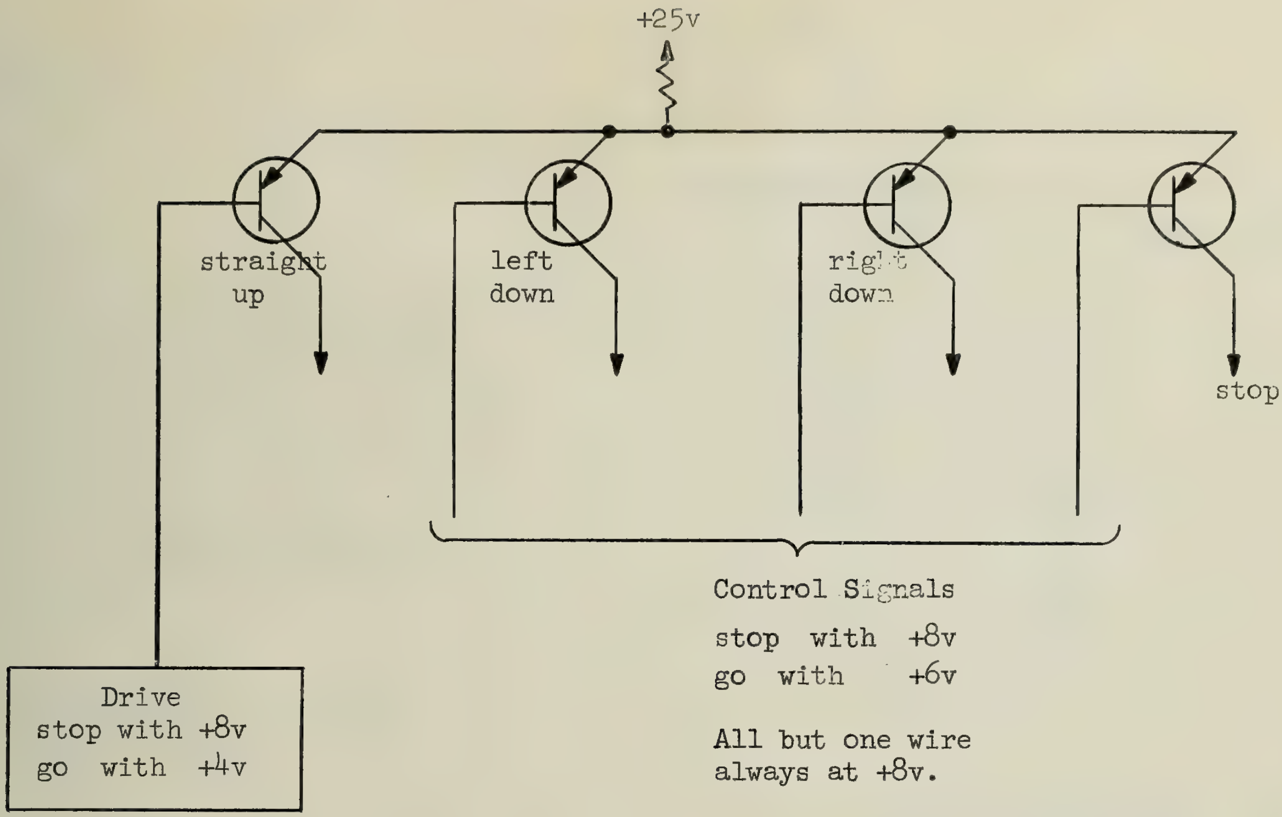


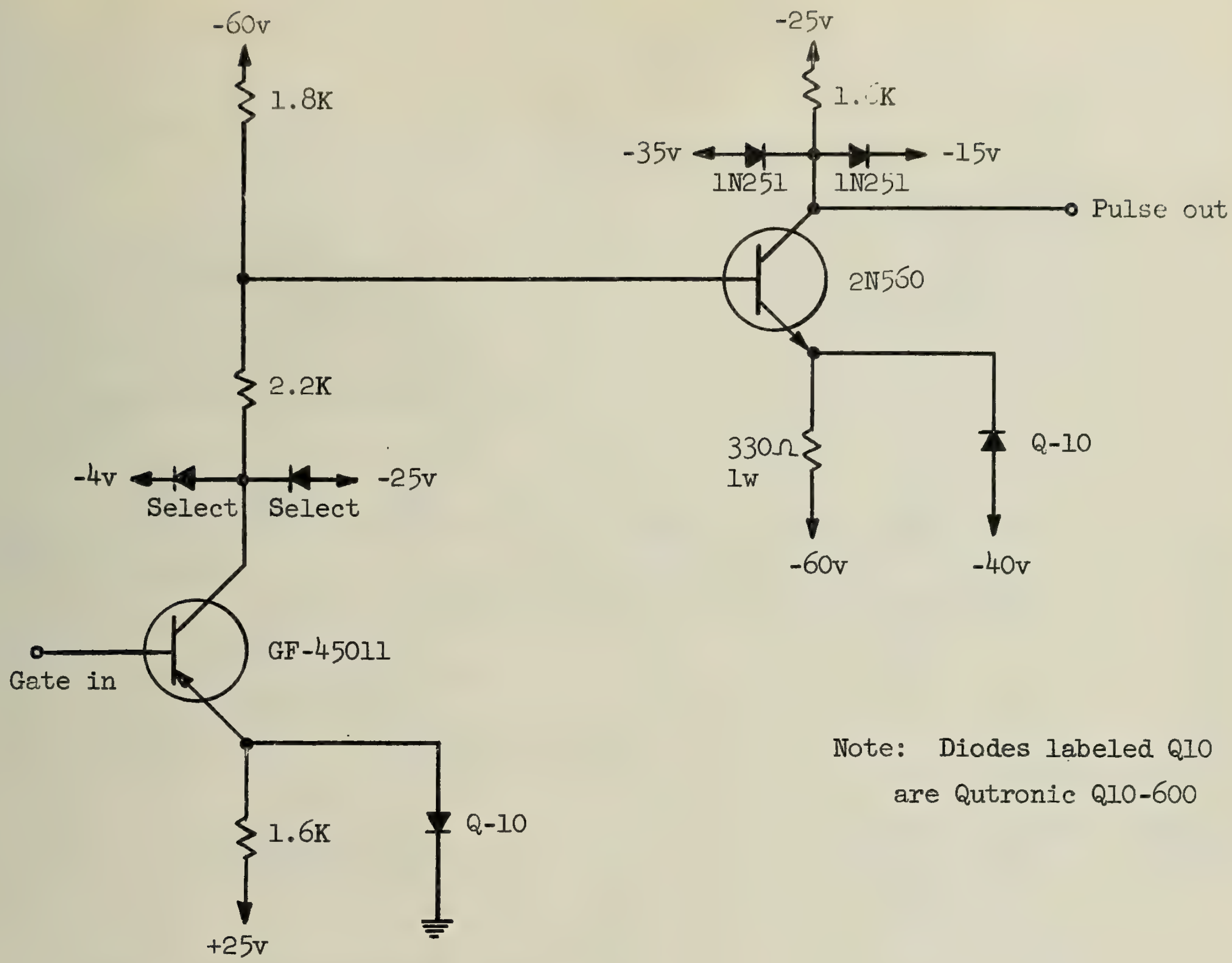
Figure 1
Difference amplifier driver with an "all stop" provision

with both the left-down and the right-down driver and also a "stop" driver which simply absorbs the switching current when none of the three others is to be energized. The input marked drive can be connected to either a logical oscillator controlled by reply back signals or a clock.

Figure 2 shows the driver designed for the flow-gating unit. Up to three flow-gating flipflops can be connected to its output, but if a total operation time of 100 mμs is desired only two flipflops should be driven. The end connections have also been designed. Work is in progress to design a new version of flow-gating in which current requirements are less severe for the drivers.

A new C-element has been designed which differs from the old type by its more straightforward philosophy: a Schmitt trigger is set by a special logical preamplifier. The circuit is shown in Figure 3.

(W. J. Poppelbaum)



Note: Diodes labeled Q10 are Qutronic Q10-600

Circuit characteristics:

Input: $\pm$.6v

Maximum driving current: 1.25ma

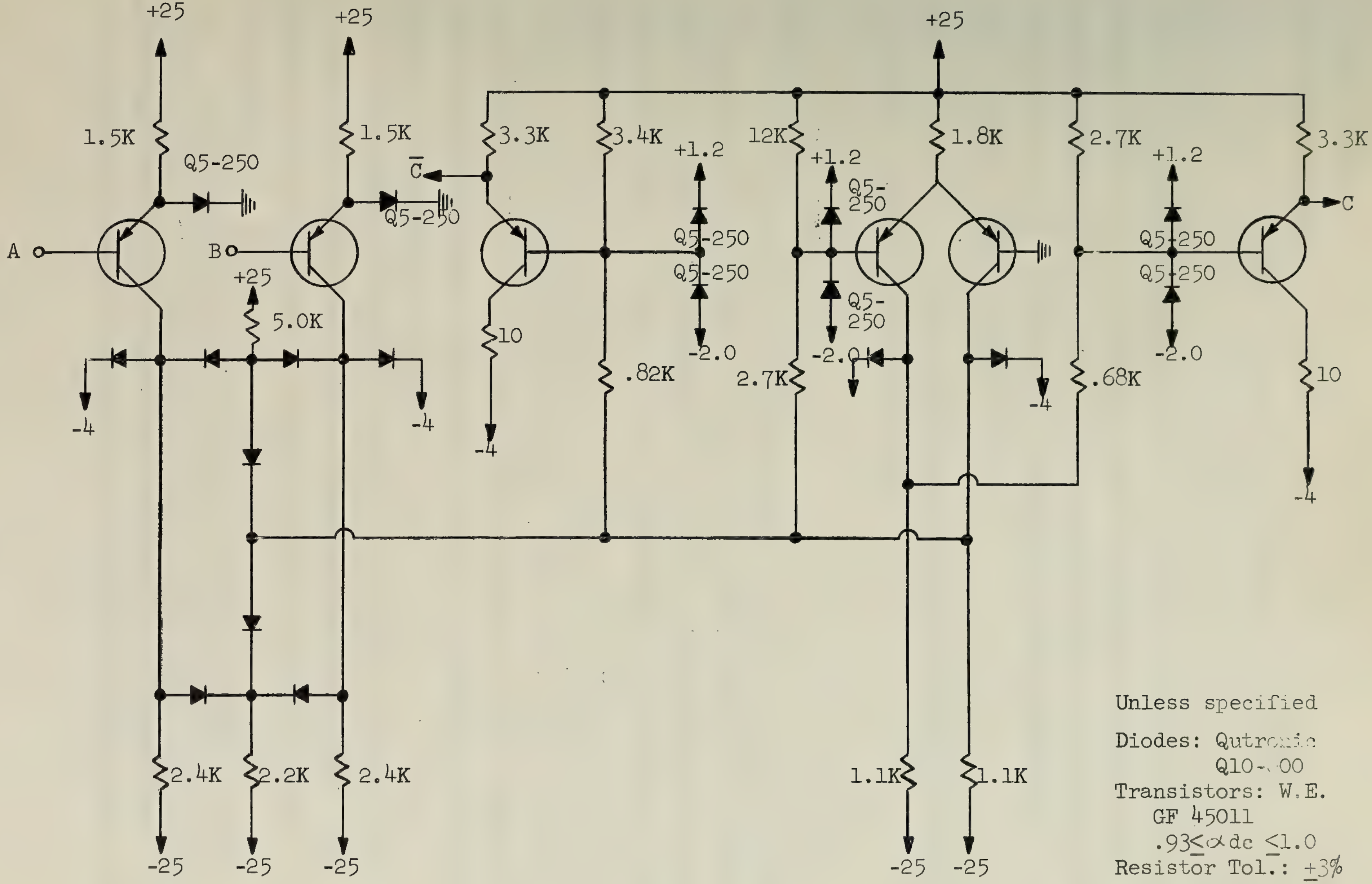
Output: -15v) -35v) 65 ma maximum

Rise Time: 600Ω resistive load: 30 mµs
Two flow-gating flipflops: 40 mµs

Fall Time: 600Ω R load: 40 mµs
Two flow-gating flipflops: 60 mµs

Figure 2

Flow-Gating Driver



Unless specified

Diodes: Qutronic
Q10-[illegible]00
Transistors: W.E.
GF 45011
$.93 \leq \alpha_{dc} \leq 1.0$
Resistor Tol.: $\pm 3\%$
Input Sensitivity:
± 0.5 volt

Figure 3

C - element using a
Schmitt trigger flipflop

3. Core Storage

Current Driver Design:

The current driver design which was reported in the October 1958 Technical Progress Report has been tested for about 200 hours. It was found to be successful in all major respects, i.e. its regulation and other important parameters were found to be within the calculated limits. The 600 ma version of the driver was found to reach the full current in about 40 mμs after the input signal crossed the center voltage between "0" and "1" and was essentially stabilized within 80 mμs after the same time reference. The calculated current regulation is $\pm$ 7.5% due to all variations except tube replacement.

The single 64 word core plane was received on January 29th. The various tests, outlined in the October 1958 Technical Progress Report, will begin as soon as mechanical supports can be fabricated.

(S. R. Ray)

Rate of Change of W Line Current:

The current in the W line when half the cores switch was simulated by setting 53 bit cores in the 1 state and 53 in the 0 state at time t = 0. Then at a later time T the switch core switched the 0's to 1's. The switch core was made of 6 XF3875 cores with 4 turns for bias, X, and Y windings and a 2 turn output winding. The W current was measured across a 5 Ω resistance. The W current could not be measured during the first 200 mμsec due to the large inductive voltage spike caused by the fast rise time of the switch core output. With 500 ma bias, X and Y drives the W line current was found to be approximately 600 ma (at .2 μsec after switching initiated) and decreasing linearly at a rate of .4 amps/μsec during the first μsec.

X-Y Transistor-Transformer Driver

An attempt was made to devise a circuit using transistors and transformers to take the place of switch cores for selecting and driving word lines. The advantage would be less delay in selecting a word and the replacement of tubes with transistors.

A one X, one Y line circuit using a total of 5 2N560 and 2 45011 transistors was tried. It operated quite well when both X and Y lines were selected, delivering 500 ma into 10 Ω secondary load using a 3:1 transformer. The half-select secondary current, however, was not predictable in the model used.

The tests will continue when a new 5:1 transformer arrives requiring only 5 transistors. The half select current problem will then be investigated in more detail.

(J. D. Leslie)

Effect of Temperature on Remanent Flux Density

A study was made on the remanent flux density vs. temperature for the RCA switch core type XF3875. The remanent flux density is defined as the amount of flux in a core when the core is in one of its bistable conditions. Measurements were taken at 25°, 50°, 75°, and 100° centigrade. The results were found to be linear, and a one degree centigrade rise in temperature resulted in a six gauss drop in remanent flux density.

(A. B. Lindquist)

High Current Transistors

The pair of Fairchild transistors — 2N696 and 2N697 — which were ordered in the hopes that they might be candidates for the high power, high current, medium speed applications in memories were tested. These transistors are unsuitable for our use because of their low betas at currents in the neighborhood of 500 ma. Their best betas seem to be at around 200 ma with a great amount of fall off after that.

(J. L. Muerle)

4. Input-Output and Auxiliary Storage

Drop-out Detector

The drop-out detector for magnetic tape recording was tested on a breadboard setup. A single stage of an F-element counter using 2N188A transistors was tested for counting rates up to 200 KC.

(C. N. Liu)

Recording Head Circuits

Transistor and thyristor performances have been compared in tests using a sample magnetic recording head as load.

Specifications have been requested from manufacturers of several transistor types thought suitable for possible application as magnetic head drivers. Characteristics of such transistors are to be incorporated in a set of recording head

specifications now in preparation.

(R. L. Cummins)

Binary Counter Circuits

A binary counter stage has been designed and built using one thyristor, two Zener diodes, and two ordinary diodes. Positive pulses are used to trigger the stage from off to on and back again in a manner similar to the action of a flipflop circuit using steering diodes. Triggering action was found to be unreliable, but the difficulty is thought to be caused by the roundness of the Zener diode knees in the neighborhood of 0.1 ma breakdown current. The work will be continued as soon as Zener diodes with improved characteristics can be obtained.

(T. A. Murrell)

PART II

MATHEMATICAL METHODS

Einstein Field Equations

(Supported in part by the National Science Foundation under Grant G-2794)

The stress energy tensor which describes a relativistic gas composed of material particles and black body radiation both at temperature T has been derived from the distribution functions of each of the components of the gas. The conservation laws are expressed by the vanishing of the divergence of this tensor and the vanishing of the divergence of the vector representing the mass flow, namely the vector obtained by multiplying the rest density into the four-velocity vector.

These conservation equations have been rewritten in terms of the behavior of the total entropy, that is the entropy of the material particles and the entropy of the radiation along the world lines of the material particles.

The Einstein field equations for a spherically symmetric distribution of such a gas will be integrated under the assumption that the total entropy is a constant throughout the distribution of the gas.

(H. Minn)

PART III

SWITCHING CIRCUIT THEORY

(Supported in part by the Office of Naval Research under contract Nonr-1834(27)

Semi-modular Circuit Theory

A representation for semi-modular circuits has been devised which is a generalization of the change chart representation for distributive circuits. This effort was described in the December 1958 Technical Progress Report, although at that time the characterization of this representation had not been completed. A set S of positive integer pairs (α,i), called changes, is defined, as in the distributive case, to have the following properties.

(i) There is an integer n such that $i \leq n$ for all (α,i) in S.

(ii) If (α,i) is in S and $\alpha > 1$, then $(\alpha-1,i)$ is also in S.

The relations between changes are somewhat more complicated than the partial ordering which occurred in the distributive case. These relations have now been worked out and are defined by means of a function B (α,i), whose range is S and whose domain consists of non-empty sets of n-vectors having non-negative integral components. The following restrictions are placed on B (α,i).

(iii) No two n-vectors in B (α,i) can be ordered numerically, that is, if a and b are in B (α,i) then we must have $a_j < b_j$ for some j and $b_k < a_k$ for some k. (This property is sufficient to ensure that B (α,i) shall be finite.)

If a is in B (α,i) then

(iv) $a_i = \alpha$, and

(v) if $a_j > 0$ and $j \neq i$ then there is a vector b in B (a_j,j) such that $b < a$, (meaning that $b_k \leq a_k$ for all k and $b_m \neq a_m$ for some m) and

(vi) if $\alpha > 1$ there is a vector c in B $(\alpha-1,i)$ such that $c < a$.

Two such representations are regarded as identical if the sets S are the same and the functions B (α,i) are also the same.

In the distributive case it is possible to show that all the sets B (α,i) contain single elements, and that as a result one can set up a partial ordering among the elements of S.

[illegible]

An equivalence may be shown to exist between the representation described above, called the B representation, and the lattice representation of a state diagram. This representation is obtained by defining a set L of n-vectors which has the following properties.

1) The vectors in L have non-negative integral components.
2) The zero vector (whose components are all zero) is in L.
3) If a and b are in L, then a v b (where a v b is the componentwise maximum of the two vectors a and b) is in L.
4) If b covers a in L (under numerical componentwise ordering) then b covers a in the set of all n-vectors having integral components.

The set L may be shown to be a semi-modular lattice under numerical componentwise ordering. Rules have also been set down for obtaining a B representation from an L representation and also for obtaining an L representation from a B representation. These rules are such that they define a one-to-one correspondence between the two representations. Under this correspondence the elements in the sets B (α, i) are all in L and are, in fact, the non-zero join irreducible elements of L.

One more condition must be placed on L in order to be certain that it corresponds to the state diagram of a circuit. If a is in L, then we may define H (a) as the set of vectors of the form b-a, where b is also in L and $b \geq a$. The condition referred to above may then be stated by saying that the number of distinct sets H (a) which one obtains is finite when one lets "a" range over L. This condition, together with 1), 2), 3), and 4) has been shown to be necessary and sufficient for the existence of a circuit corresponding to L. A corresponding condition is now being sought for the B representation. While this final condition is not necessary when dealing with finite L and finite S, it must always be imposed in the infinite case, and leads to the development of a theory of periodicity similar to the cycling theory of Report 78.

The importance of the B representation is two-fold. First, it simplifies the theoretical treatment of circuits and provides a tool for handling the very difficult problems associated with delays in lines and differences in discrimination levels as well as problems of a more theoretical nature. Second, it permits the change chart synthesis procedure to be extended to semi-modular circuits in a natural and constructive way.

(J. H. Shelly)

PART IV

ILLIAC USE AND OPERATION - GENERAL LABORATORY INFORMATION

Machine Use

During January specifications were presented for 17 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1272. Numbers followed by T are for theses.

1272 Electrical Engineering. Frequency Response of Tuned Amplifiers. The magnitude and phase responses of several types of tuned amplifiers whose response can be specified by pole and zero locations in the complex frequency plane are to be computed and compared. Illiac will be used to compute the above and output the data in the form required by the data plotter. The curves will be plotted by the data plotter. Mathematically, the magnitude and phase of equations of the form

$$T(jw) = K\frac{(jw - So_1)(jw - So_2)\ \ldots\ (jw - So_i)}{(jw - Sx_1)(jw - Sx_2)\ \ldots\ (jw - Sx_j)}$$

are to be computed and plotted vs. w. So_i and Sx_j are complex numbers. Each factor $(jw - So_i)$ will be evaluated as to magnitude and phase and combined with the other factors to give the over-all $|T|$ and average T vs. w.

1273 T Animal Science. Phosphorus Requirement of the Weanling Pig. The research problem is to determine the phosphorus requirement of the pig. Various levels of phosphorus are fed to the pig and data collected on response criteria, such as weight gain, bone ash, etc. The Illiac will be used to determine the requirement by fitting lines to the data using the method of least squares to show that point above which added phosphorus does not increase the response criteria.

1274 T Animal Science. The Tryptophan Requirement of the Weanling Pig and Rat. This problem is to determine the minimum amount of tryptophan required to permit maximum weight gain in the weanling pig and albino rat. The problem will be solved by the method of least squares.

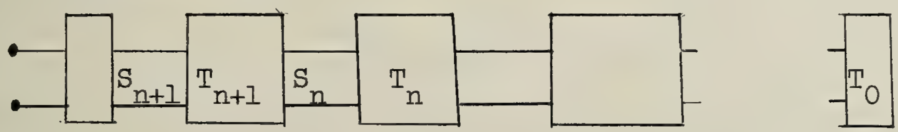
1275 Animal Science. Calculation of Coefficients of Inbreeding and Relationship. From time to time it is desired to calculate certain coefficients of inbreeding and relationship as part of the work of following a breeding program, of characterizing the individuals at any given time, and of deciding on future matings. The arithmetic to be accomplished is almost entirely the evaluation of

$$\sum_{A} \left(\frac{1}{2}\right)^{n+n'+1} (1 + F_A) = N_{PQ}$$

where A is an ancestor of both P and Q, n and n' generations back, respectively, and $F_A = N_{SD}/2$, where S and D are the parents of A. The program being written will take a herd or flock pedigree and calculate N_{PQ} for every possible pair of individuals in the pedigree.

1276 Electrical Engineering. Morse Code Punch Routine. The Illiac will be used to prepare output tapes which in turn are to be used to automatically key an oscillator or transmitter.

1277 Electrical Engineering. Logarithmically Periodically Loaded Transmission Line. This program calculates the voltage and current distribution and the input impedance of a transmission line that is logarithmically periodically loaded with a general four-terminal network whose elements are a function of frequency and position along the line.



The program performs the routine matrix multiplications after it calculates $[S_n]$ and $[T_n]$.

$$[S_n] = \begin{bmatrix} \cos s & j \sin s \\ j \sin s & \cos s \end{bmatrix} \qquad s = j\, 2\pi\, p(1 - \tau)\tau^n c$$

$$[T_n] = \begin{bmatrix} t_0 & t_1 \\ t_2 & t_3 \end{bmatrix}$$

where

$$t_i = \frac{a^i_m (\tau^n p)^m + a^i_{m-1} (\tau^n p)^{m-1} + \ldots + a^i_0}{b^i_m (\tau^n p)^m + b^i_{m-1} (\tau^n p)^{m-1} + \ldots + b^i_0} \qquad \begin{array}{l} i = 0, \ldots, 3 \\ m \leq 32 \end{array}$$

and a^i_m, b^i_m, τ, c, n, m are all specified on a data tape. The independent variable is p, the complex frequency. The program computes and prints out V^-_n, I^-_n, V^+_n, I^+_n.

$$\begin{bmatrix} V^-_n \\ \\ I^-_n \end{bmatrix} = \begin{bmatrix} \\ T_n \\ \\ \end{bmatrix} \begin{bmatrix} V^+_{n-1} \\ \\ I^+_{n-1} \end{bmatrix}$$

and

$$\begin{bmatrix} V^+_n \\ \\ I^+_n \end{bmatrix} = \begin{bmatrix} \\ S_n \\ \\ \end{bmatrix} \begin{bmatrix} V^-_n \\ \\ I^-_n \end{bmatrix}$$

V^+_0 and I^+_0 are also specified.

1278 T Computer. Monte Carlo Matrix Inversion. Given a matrix equation $\underset{\sim}{x} = \underset{\sim}{a} + \underset{\sim\sim}{kx}$, where $\underset{\sim}{a} \equiv (a_1, a_2, \ldots, a_n)$ and

$$\underset{\sim}{k} \equiv \begin{pmatrix} k_{11}, & k_{12}, & \ldots & k_{1n} \\ & \ldots & & \\ k_{n1}, & k_{n2}, & \ldots & k_{nn} \end{pmatrix}$$

are known, or an equivalent integral equation, $x(\xi) = a(\xi) + \int k(\xi, \eta)\, x(\eta) d\eta$, we can formally get the solution $\underset{\sim}{x} = (\underset{\sim}{I} - \underset{\sim}{K})^{-1} \underset{\sim}{a} = \underset{\sim}{a} + \underset{\sim\sim}{ka} + \underset{\sim\sim}{k^2 a} + \ldots + \underset{\sim\sim}{k^5 a} + \ldots$, which converges if max. modulus of eigenvalues of $\underset{\sim}{k} < 1$.

<u>Method 1</u>. For a random walk $\Gamma_m \equiv (i_0, i_1, \ldots, i_{m-1}, i_m)$ calculate a score

$$S_{i_o}(\Gamma_m) = a_{i_o} + \frac{k_{i_o i_1}}{p_{i_o i_1}} a_{i_1} + \frac{k_{i_o i_1}\, k_{i_1 i_2}}{p_{i_o i_1}\, p_{i_1 i_2}} a_{i_2} + \ldots + \frac{k_{i_o i_1} \cdots k_{i_{m-1} i_m}}{p_{i_o i_1} \cdots p_{i_{m-1} i_m}} a_{i_m}$$

where p_{ij} is the probability of a jump $i \rightarrow j$. 'Border' the problem by introducing a zero suffix, for which $a_o = x_o = 0$, $k_{io} = 0$, $p_{oi} = \delta_{oi}$ (i.e., 1 if i = 0, 0 otherwise). This causes the walk to give a terminating score, without bias.

$E[S_{i_o}(\Gamma_m)] \rightarrow x_{i_o}$ as $m \rightarrow \infty$, or at termination. Also

$$\mathrm{var}(S_{i_o}) = \sum_{i_1=1}^{n} \frac{k_{i_o i_1}^2}{p_{i_o i_1}} \left[\mathrm{var}(S_{i_1}) + x_{i_1}^2\right] - \left(\sum_{i_1=1}^{n} k_{i_o i_1} x_{i_1}\right)^2 .$$

Method 2. If all a_i and $k_{ij} \geq 0$, we may choose, in theory, $p_{ij} = k_{ij} x_j / \Sigma_h k_{ih} x_h$, giving zero variance. Thus, the method makes a sequential approximation to x_j by the best available estimate at each stage and uses p_{ij} calculated accordingly. A convergence of variance as $s^{-2(p+1)} \exp\left[(p+1)\ (N(p+1) - 1)(1 - \frac{1}{s})\right]$, where s is the stage number and p is a parameter (integer ≥ 1) used in averaging, is anticipated. Optimum p for an S-stage process is $\left[(\log S/N(1 - \frac{1}{s})) + \frac{1}{2N} - 1\right]$. N is a constant of the system, equal to M/(1-M), when

$$M = \max_i\left(\Sigma_j \frac{k_{ij}}{x_j} \Sigma_h k_{ih} x_h\right) < 1, \text{ by hypothesis.}$$

Method 3. Given an approximation $\underset{\sim}{X}$ to $\underset{\sim}{x}$, we have that $\underset{\sim}{y} = \underset{\sim}{x} - \underset{\sim}{X}$ satisfies $\underset{\sim}{y} = \underset{\sim}{\Delta} + \underset{\sim}{K}\underset{\sim}{y}$, where $\underset{\sim}{\Delta} = \underset{\sim}{a} + \underset{\sim}{K}\underset{\sim}{X} - \underset{\sim}{X}$. Thus, this method sequentially replaces the original $\underset{\sim}{a}$ by successively smaller $\underset{\sim}{\Delta}$, reducing the variance geometrically.

The purpose of the experiment is to investigate the relative efficiencies and convergence characteristics of the three methods.

1279 T Theoretical and Applied Mechanics. Stresses in Short Excentrical Columns. The problem is to determine the sum of principal stresses from photoelastic data. The method used is the standard solution of the La Place equation by the Liebmann method, Library Program G-1.

1280 Control Systems Laboratory. Study of Resonant Binary Digital Shift Register. The resonant binary digital shift register under study is described mathematically by nonlinear differential equations containing many parameters. Obtaining solutions of these equations subject to variation of the parameters requires the use of Illiac.

1281 Psychology. Family Ratings. This study is involved in developing a rating scale for rating the family unit. Intercorrelations and factor analyses are to be used to determine the relationships between different items and also between different classifications of families. Reliabilities of both the items and the family classifications are to be obtained. Programs from the Social Science Library of Tapes will be used in carrying out this research.

1282 Chemistry. The integral, $\int_0^R \bar{\zeta}_{m,n}(i, t_j \Upsilon) \ell^{-kt} t^p \, dt$, will be evaluated for many values of the parameters.

$\bar{\zeta}_{m,n}$ is a tabulated function of t; p is integral.

1283 Education. The Measurement of Critical Thinking. Data have been collected for 587 subjects on three critical thinking tests, namely, the Watson-Glaser Critical Thinking Appraisal (99 items), A Test of Critical Thinking prepared by the American Council on Education (52 items), and a Test on the Principles of Critical Thinking prepared by the Illinois Curriculum Program Committee (53 items). Since the makers of these tests claim that the tests measure the domain of critical thinking, it is proposed in this research to test their claims by making an analysis of each test separately and finally by making an analysis of a composite test. The following procedures will be used:

1. Scores for the twenty subtests contained in the three critical thinking tests will be factor analyzed. Pearson r coefficients will be computed and centroid factors extracted. Rotation to oblique simple structure will follow.

2. From the 587 subjects will be deleted those who are suspected of being pathological doubters. Criterion for selecting these doubters is the number of errors made in a section of the Watson-Glaser test containing 65 items which seem to be keyed to favor the pathological doubter. For the remaining subjects, individual test item scores for all three tests will be factor analyzed. Phi coefficients will be computed and centroid factors extracted, followed by rotation to oblique simple structure.

3. An attempt will be made to correct for the factor of pathological doubting by carrying out a factor analysis of covariances using individual item scores for all three tests for the 587 subjects.

4. Multiple choice items on all three tests will be rescored using scale values instead of zero or one. A factor analysis will be made of a composite test made up of all such items (approximately 75). Pearson $\underline{r}$ coefficients will be calculated, and centroid factors extracted. Rotation to oblique simple structure will follow.

5. A random sample of the 587 subjects will be obtained. Individual item scores for the three tests for subjects in the random sample will be factor analyzed using phi coefficients, the centroid method with rotation to oblique simple structure. The purpose here is to obtain a clue regarding the size of an efficient sample when factor analyzing. In order to reach a conclusion here, this procedure may have to be carried out more than once.

1284 State Water Survey. Solution of Nonequilibrium Formula for Drawdown in Water Wells. The nonequilibrium formula for drawdown in water wells is:

$$s = \frac{114.6\ Q}{T} \int_u^\infty \frac{e^{-u}}{u}\, du ,$$

where $u = \dfrac{1.87\ r^2 S}{Tt}$

s = drawdown in feet at observation well

Q = discharge of pumped well in gallons per minute

r = distance in feet from pumped well to observation well

t = time in days since pumping began

T = coefficient of transmissibility in gallons per day per foot

S = coefficient of storage, fraction.

The value of the integral can be approximated by summation of the following series:

$$-0.577216 - \log_e u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} - \frac{u^4}{4.4!} + \ldots$$

Interpretive orders for use with A-6 have been prepared and are ready for code checking.

1285 State Water Survey. Precipitation Distribution. There are many rather long-term Illinois precipitation records available on punch cards. With help from the Illiac, it will be possible to study the distribution function for Illinois

precipitation in space and time. The objective will be to either develop a distribution function for Illinois precipitation or to determine which frequency distributions in current use, such as the normal, log-normal, and others, may be most applicable in describing precipitation data.

1286 Natural History Survey. The Use of the Lens for Age Determination in the Cottontail Rabbit. A group of 92 cottontail rabbits were raised in the laboratory and killed periodically over a period of 30 months. The lenses of the eyes were removed, dried, and weighed. The lens growth curve was plotted and found to be similar to a log curve. It is desired to fit the curve with the Illiac by the method of least squares. Because the lens grows throughout life and there is little individual variation in the lens growth curve, it will be possible, once the curve is established, to estimate the age of unknown age rabbits. One use of this technique will be to make a life table for the species.

1287 Psychology. Some Parent-Child Influences. This problem seeks to relate certain personality characteristics of children to certain attitudes or practices on the part of their parents. The child variables studied are such as dependency, aggression, and stubbornness. The cases (children and their parents) were obtained from cases at the Champaign County Mental Health Clinic. Measurements by clinical and other means have been obtained for 25 child variables and 25 parental variables on 31 cases. It is desired (1) to calculate the Pearson product-moment correlation coefficients interrelating the 50 variables, and (2) to calculate 36 partial correlations for pairs of two variables with a third variable held constant.

1288 Student Counseling Service. Contribution of High School Rank and Quality-Index to Prediction of College Freshman Grades. This is a study to determine how much the prediction of college grades from freshmen-guidance test scores would be improved by including measure of high-school rank and high-school quality in the predictions. Only standard Illiac library routines are involved.

[illegible]

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[illegible]

Table I shows the distribution of machine time for the month of January.

TABLE I

	Hrs:Min	
Regular Maintenance	31:34	
Unscheduled Maintenance	9:13	
Drum Engineering	29:55	
R.A.R.	4:35	
Leapfrog	34:00	
Library Development	4:35	
Wasted	:00	
		113:52

Use by Departments

Computer	47:42	
Physics	13:04	
Control Systems Laboratory	59:56	
Structural Research	53:00	
Struct. Res. (AF 464)	23:59	
Struct. Res. (A.A.S.H.O. Rd. Test)	3:52	
College of Medicine	:37	
Psychology	12:33	
Sociology	3:38	
Inst. of Com. Res.	4:38	
Inst. of Com. Res. (9067C)	1:22	
Education	:30	
Bureau of Educational Research	5:38	
Economics	8:25	
Theor. and Appl. Mech. (ORD 593 IC)	3:52	
Mechanical Engineering	3:21	
Mech. Eng. (ORD 1980)	:27	
Mech. Eng. (Inst. of Boiler Rad. Mfg.)	:06	
Min. and Met. Eng. (AF 3789)	:02	
Electrical Engineering	4:00	
Elect. Eng. (BOEING)	1:21	
Elect. Eng. (AF 6079)	1:19	
Chemistry	86:04	
Agriculture	20:09	
State Dept. of Public Welfare (1715)	3:20	
State Water Survey	2:10	
State Water Survey (SC 75055)	2:00	
Michael Reese Hospital, Chicago	:30	
Eastern Illinois University (Botany)	:45	
Classes	27:27	
Miscellaneous	13:03	
		408:50
TOTAL		522:42

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance, and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for January.

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	SCHEDULED ENGINEERING	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/2/59	21:48	:17	1	(1) Physical Plant worker tripped AC switch	1:55	:00	2:38	0
1/5/59	21:00	:00	0		3:00	:00	:58	0
1/6/59	17:01	3:59	3	(1) Error during A.M. maintenance extended beyond 10 a.m. (Memory 2^{-30}) (2) Drum failure (3) +300 v. power supply	3:00	:00	:21	0
1/7/59	19:33	1:38	2	(1) Repair beyond 10 a.m. Arithmetic switch tube bad (2) Memory control	2:49	:00	:40	0
1/8/59	18:56	2:04	2	(1) Control error (leapfrog) (2) Input error	3:00	:00	1:10	1
1/9/59	19:54	2:06	3	(1) Memory 2^{-25} (2) Reader "F" error (3) Leapfrog (arithmetic failure)	2:00	:00	2:00	1
1/12/59	20:59	:01	1	(1) Memory, control error	3:00	:00	:39	0
1/13/59	16:15	4:45	3	(1) Maintenance past 10 a.m. Trouble Memory 2^{-22} (2) 2^{-22} Memory (3) Memory control error	3:00	:00	3:11	2
1/14/59	19:12	1:48	2	(1) Maintenance past 10 a.m. pos. 2^{-12} (2) Drum failure	3:00	:00	1:12	0
1/15/59	20:59	:01	1	(1) Drum failure	3:00	:00	:40	0
1/16/59	22:00	:00	0		2:00	:00	:40	0
1/19/59	20:00	1:10	1	(1) Drum failure	2:50	:00	:39	0
1/20/59	20:58	:02	2	(1) Drum failure (2) Drum failure	3:00	:00	:39	0
1/21/59	21:00	:00	0		3:00	:00	:40	0

[illegible]

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	SCHEDULED ENGINEERING	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
1/22/59	20:29	:31	1	(1) Drum failure	3:00	:00	:26	0
1/23/59	21:47	:13	1	(1) Reader "B" error	2:00	:00	:50	0
1/26/59	20:59	:01	1	(1) Drum failure	3:00	:00	:41	0
1/27/59	20:58	:02	2	(1) Input error (2) Input error	3:00	:00	:41	0
1/28/59	20:58	:02	1	(1) Leapfrog arithmetic error	3:00	:00	:49	1
1/29/59	21:00	:00	0		3:00	:00	:50	0
1/30/59	21:42	:18	1	(1) Power supply off	2:00	:00	1:00	0
TOTALS	427:28	18:58	28		57:34	:00	20:22	5

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				[illegible]				
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

TABLE III

Error Summary for January

Memory	8
Control	1
Input	3
Reader	2
Arithmetic	3
Power Supply	2
Drum	8
Other	1
Total	28

Reports and Seminars

Seminars

"A Theory of Linear Sequential Networks and Some Possible Extensions", by Dr. Bernard Elspas, Stanford Research Institute, Menlo Park, California, January 5

"M-460 - A Computer Designed for Real-Time Data Processing", by Mr. Mark Koschmann, Remington-Rand Univac, St. Paul, Minnesota, January 12

"Problems of Data Reduction Connected with Hydrogen Bubble Chambers", by Dr. Arthur H. Rosenfeld, Radiation Laboratory, University of California, Berkeley, California, January 23

Personnel

The personnel associated with the department and, hence, the contributors to this report are:

Bahls, James E., Jr. Laboratory Mechanic
Beardwood, Miss Jillian E., 1/2-time Research Assistant
Belford, Mrs. Geneva G., 1/2-time Research Assistant (resigned January 31)
Bivins, Robert L., AEC Fellow
Blencoe, Robert W., Computer Operator I (started January 29)
Bowes, Mrs. Doris E., 1/2-time Research Assistant
Buenger, George E., 1/2-time Research Assistant
Carter, Clifford E., Electronics Engineer for Illiac
Chow, Yuan S., Research Associate

Clark, Miss Helen B., Secretary
Cummins, Richard L., Research Assistant
Dickman, Kern W., Research Assistant
Ellsworth, Mrs. Jean E., Clerk-Stenographer II
Fileccia, John L., Electronics Technician I
Flenner, Ross H., 1/2-time Research Assistant
Fosdick, Lloyd D., Res. Asst. Prof. of Physics
Foster, Merlin J., Computer Operator I
Foulk, Clinton R., 1/2-time Research Assistant
Gear, Charles W., 1/2-time Research Assistant
Gillies, Donald B., Res. Asst. Prof. of Appl. Math.
Golub, Gene H., Research Assistant (until January 31)
Gray, Mrs. Mary T., Research Assistant
Guckel, Henry, 1/2-time Research Assistant
Gustafson, Ronald A., Electronics Technician I
Halton, John H., 1/2-time Research Assistant
Huffman, W. Logan, Computer Operator II
Johnson, Noel H., 3/4-time Research Assistant
Kerkering, Thomas E., Sr. Laboratory Mechanic
Krabbe, Shirlie P., Electronics Technician II for Illiac
Hammersley, John M., Visiting Lecturer in Mathematics
Handscomb, David C., 1/2-time Research Assistant
Leslie, James D., 1/2-time Research Assistant
Lindquist, A. Bruce, 1/2-time Research Assistant
Liu, Chao-ning, 1/2-time Research Assistant
Lopeman, Harold E., Electronics Engineer
Marcer, Peter J., 1/2-time Research Assistant
Meagher, R. E., Head of the Laboratory
Metze, Gernot A., Research Associate
Michael, George W., Administrative Assistant
Minn, Hokee, 1/2-time Research Assistant
Muerle, John L., 3/4-time Research Assistant
Muller, David E., Res. Assoc. Prof. of Appl. Math.
Murrell, T.A., Assoc. Prof. of Elec. Eng.
Oare, John W., Draftsman
Olsen, Warren G., 1/4-time Draftsman (resigned January 23)
Pelg, Edmund, Electronics Technician I
Penny, Samual J., 1/2-time Research Assistant
Poppelbaum, W. J., Res. Asst. Prof. of Elec. Eng.
Purcell, Kenneth G., Jr. Laboratory Mechanic
Ray, Sylvian R., 1/2-time Research Assistant
Richardson, Warren V., Office Machines Tech. I
Robertson, James E., Res. Assoc. Prof. of Elec. Eng.
Rosenkrantz, Walter A., 1/2-time Research Assistant
Rudman, Mrs. Linda G., Computer Teletype Operator
Russell, Miss Ramona J., Computer Operator I
Schleifer, Martin N., 1/2-time Research Assistant
Serio, Frank P., Electronics Technician I
Shannon, Mrs. Katherine K., 1/2-time Research Assistant
Shelly, James H., 3/4-time Research Assistant

Snyder, James N., Res. Prof. of Physics
Sullivan, John D., Electronics Technician I
Taub, A. H., Res. Prof. of Appl. Math.
Toy, Mrs. Renee D., Clerk-Stenographer II
Webber, Carl E., 1/4-time Research Assistant (resigned January 31)
Wenta, Joseph V., Sr. Elec. Technician for Illiac
Wiseman, Neil E., 3/4-time Research Assistant

Georgia Institute of Technology Staff at Illinois

Lenoir, S. Paine, Jr.

The Department Advisory Committee consists of Professors L. D. Fosdick, D. B. Gillies, D. E. Muller, W. J. Poppelbaum, J. E. Robertson, J. N. Snyder and A. H. Taub.

Digital Computer
University of Illinois
Financial Report

January 31, 1959

	Digital Computer	U.S. AEC 415	Digital Computer Ind. Cost.	Soc. Sci. Research Council	Computer Service	National Science Foundation	U.S. Navy Task 15	U.S. Navy Task 30	Total
Free Balance	6,534.78 [1]	155,596.58 [2]	2,061.85	2.60	48,720.88	3,633.77 [3]	42,155.29 [4]	17,847.65 [5]	276,553.40
Equipment	9,046.71	4,452.50		697.40	50,641.38				64,837.99
Matl./Supplies	8,657.54	191,963.52			117,486.47	367.33	23.52	116.95	318,615.33
Sal./Wages	79,283.73	98,568.42			223,920.86	23,533.00	14,312.30	81,701.09	521,319.40
Overhead		36,710.59				3,916.82	5,320.11	31,314.31	77,261.83
Work. Comp.		1,751.58				310.04	249.52	1,574.40	3,885.54
Retirement		2,706.00			163.20	307.24	334.59		12,039.73
Travel	246.66	6,005.52			2,601.85	195.10	1,119.95	1,870.65	5,479.92
Tele./Teleg.	1,012.77	2,245.29			2,027.31	36.70	28.30	129.55	5,479.92
Building	646.80				365.78				1,012.58
Total	98,894.21	344,403.42		697.40	397,206.85	28,666.23	21,388.29	116,706.95	1,007,963.35

Funds Expended - Previous Allowances	1,231,689.21
Total Expenditures, 2/1/49 to date	2,239,652.56

1. Through June 30, 1959 (Exp./Wages Only)
2. Through Nov. 30, 1959
3. Through Aug. 31, 1960
4. Through Oct. 31, 1960
5. Through June 15, 1959

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

February 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The Rich Electronic Computer Center at Georgia Institute of Technology is participating in this work by the support of a staff member at the University of Illinois.

1. Tolerance Analysis

A new scheme for optimizing circuit parameter tolerances has been developed. In brief, this procedure may be described as follows. The desired operating conditions of the circuit are expressed as a set of inequalities

$$g_i(R_1, R_2, \ldots, R_n; S_1, S_2, \ldots, S_p) \leq G_i, \quad (i = 1, 2, \ldots, m)$$

where the g's are functions of the n variables of the circuit $R_1, \ldots, R_n$, and p parameters of the circuit. It is desired to find an operating point characterized by a particular set of values for $R_1, R_2, \ldots R_n$, for which the tolerances on the variables are "optimum" (i.e., that the largest variations, consistent with the inequalities above, are permitted). Starting with an initial set of variables for which the conditions are satisfied, the variables are varied one at a time in a search for upper and lower bounds R_j(upper) and R_j(lower) and a new $R_j = \frac{1}{2}(R_j[\text{upper}] + R_j[\text{lower}])$ defines the j^{th} coordinate of the next point in the iteration scheme. This process continues until the changes in the values of the R_j's are less than some pre-assigned number. This procedure can be shown to locate the optimum point in certain highly simplified cases. In practical cases it appears to locate points for which the permitted tolerances have relatively large values. The procedure has been incorporated into a program for the Illiac. In the two cases run, an inverter circuit (3 variables, 4 conditions) and an asymmetric flip-flop (5 variables, 9 conditions) have been treated. The running time for the first case was about four seconds, and for the second, about 20 seconds. The operating point located in the first case permitted variations of the order of 10%. The

study of the second case has not been completed, but the indicated individual tolerances on the parameters are about 10%.

(L. D. Fosdick, W. J. Poppelbaum, N. E. Wiseman)

2. Shifting Register Test Unit

The endurance run which had been started on January 20, 1959, continued for 657.0 hours until February 17, 1959. At that time a transistor with intermittently high V_{EB} fwd caused improper gating of a flipflop. A slowdown of the G4 shift time by about 10 mμs was found to have been caused by a transistor which passed all static tests. Replacement by other transistors improved the operation somewhat.

The gate drivers were modified to correspond to a later tolerance-analyzed design. This entailed replacements of a resistor, removal of a 20 μμf bypass capacitor which had been added to reduce the sensitivity to noise, and raising of the nominally 6.5v emitter bump supply of the switching transistors from 5.8v to 6.3v. The 20 μμf bypass capacitors had to be reinstalled in the G1 and G3 drivers in order to suppress spikes.

On February 19, 1959, all transistors were checked. Ten transistors were found to be out of tolerance.

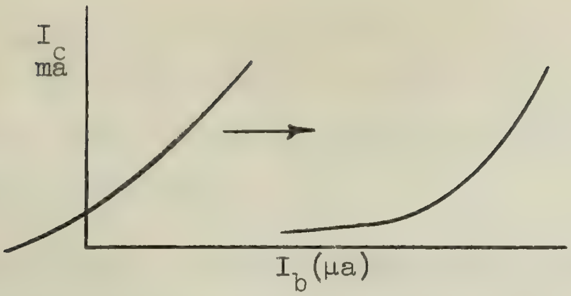
Another endurance run was interrupted because the pilot light serving as a fuse in the DC turn-on box burned out and switched off all power to the unit.

An endurance run was started on February 23, 1959. At noon on March 1, 1959, the unit had completed 146.0 hours of errorfree operation and was continuing to run.

(G. Metze)

3. Core Storage

Time was spent on the design of the input stage of a new sense amplifier suggested by Professor W. J. Poppelbaum. It was hoped that by adding resistance to the emitter of a GF45011 transistor, the common-emitter-current-transfer characteristics (I_c vs. I_b) could be shifted to the right as shown on the following page.



The purpose was to shift the curve far enough to the right so that the collector current cut-off would be at 200 μ amps, which is the peak amplitude of the noise current on the sense wires. However, laboratory tests proved that for the GF45011, this could not be done. The possibilities of first amplifying and then using a hysteresis network to feed a Schmitt trigger flipflop will be investigated.

(A. B. Lindquist)

A pair of Transitron 2N546 transistors has been ordered for use as a memory driver. The search for fast, high-current transistors is continuing. A considerable amount of time was spent checking calculations on the equivalent circuit of the wires in a core plane. Some time was also devoted to preliminary design of a 4-word 3-bit diode enhancement current memory using transistor drivers.

(J. L. Muerle)

The design of a timer (stable to at least ± 5%) with pulse length adjustable from 50 mμs to 1.5 μs was undertaken. The timer designed requires two flipflops, three AND, one OR and one NOT circuits and a variable delay unit. A Miller integrator circuit was investigated as the delay unit, but was abandoned because the variations in length of delay would have been greater than 5% due to component tolerances. A tapped delay line is now being considered, and one 100 mμs line has been built.

(J. D. Leslie)

4. Input-Output and Auxiliary Storage

Design of a gated output flipflop, for use in a ring counter, was studied using the Illiac 1206 analysis routine. Investigation of the state of the art of magnetic recording head manufacture was continued with the mailing of tentative specifications with a letter of inquiry to one manufacturer. Delivery of the magnetic tape transport is expected in March, 1959. Instruments (running time meters, mechanical counters) were ordered for recording data concerning operating

life and component reliability of the transport. An initial supply of one type of magnetic tape will be delivered with the new machine; a sample of another brand of computer-grade tape has been ordered for testing, and a laboratory sample of still a third type has been received.

(R. L. Cummins)

The investigation into the use of thyristors to reduce current rise time in a magnetic tape recording head was continued. All indications are that the opposite effect, a slight increase in rise time, is to be expected. Circuits other than an emitter driver are at present being considered.

(T. C. Piper)

A study is being made of peak-sensing schemes for magnetic tape recording. A preamplifier with a gain of 200 and a band width of 2 megacycles is being designed for amplification of readback signals. A 4-stage F-element counter was completed by the shop, and is being tested. The counter, using GE 2N188A transistors, is capable of counting rates up to 250 kc.

(C. Liu)

A visit was made early in February to Texas Instruments, Inc. at Dallas. They expect to develop, within the next six months, two new transistor types that may be capable of driving a low-inductance, high-current tape head with rise times of one-half microsecond. They also arranged to send us five samples of each of the following Zener diode types, IN758A, IN759A, and IN1816C, which have been received recently. Tests of the first two types show remarkably sharp breakdown knees; they will be tried in the thyristor counter stage. A "worst-case" analysis of the drop-out detector circuit, including transient switching conditions, has revealed one trouble spot in the multivabrator section where the allowable emitter-base reverse voltage is exceeded. A simple modification to correct this fault will probably decrease the timing accuracy, but in the proposed application the accuracy required is not very high.

(T. A. Murrell)

5. Basic Circuits

All the basic circuits, with the exception of the C-element and the two-wire EXCLUSIVE OR, have been redesigned for the new set of supply voltages (+25v, -50v, -5v, -3.1v, +2.2v) and for the use of the new type of Transitron diode characterized by 0.41 - 0.45v forward drop at 10 ma. Drawings of these circuits are now being

made. Since the diodes have not yet been delivered, actual testing of the circuits has not been possible except with substitute diodes.

(N. E. Wiseman)

An attempt has been made to investigate the choice of return voltages from a more general point of view--optimization of current gain, saturation margin and output swing. The essential result of these calculations is that the collector return voltage should be greater (in absolute values) than the emitter return voltage. Another set of calculations was made to express the circuit operation time as a function of the circuit parameters. These calculations will have to be verified experimentally.

(W. J. Poppelbaum and N. E. Wiseman)

A study of driver requirements and peculiarities was made for the purpose of obtaining an optimum design of shift-gate drivers. Specifications for the output were set at ±1.0v nominal with ±2 ma per base to be driven. Consideration of diode time constants seems to indicate that the unhooking of bump diodes is not a prime factor in limiting driver speeds. Figure 1 below shows a driver for driving 53 gates. As will be noted, no Zener diodes are used. The non-standard bump voltages could be produced locally by silicon diodes.

(W. J. Poppelbaum and M. N. Schleifer)

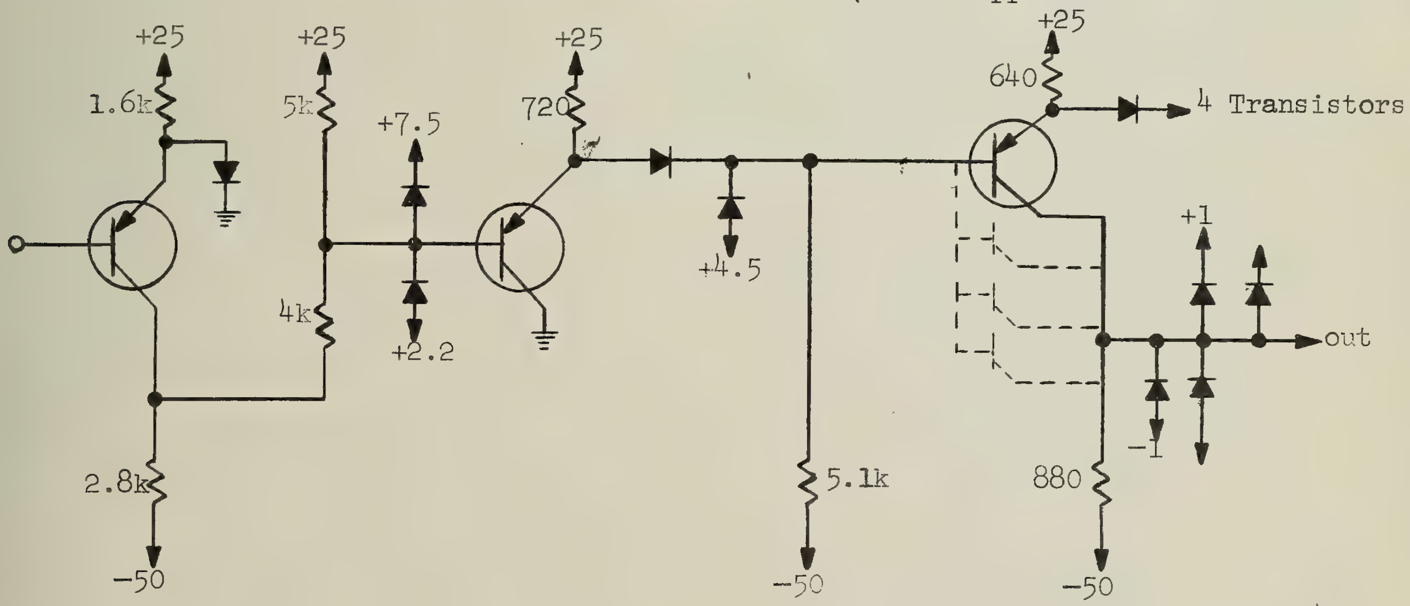


Figure 1

Driver for 53 Bases at 2 ma, ± 1v

For flow-gating the input-level changers, the output-level changers and the drivers were completed and tolerance analyzed. These circuits are now being drawn for the circuit book. A 3-register, 3-bit test unit is presently being assembled in order to test the whole assembly under actual working conditions. Simultaneously, the work on "partial flow-gating" has shown some results in the case of high-gain Eccles-Jordan flipflops with flow-gating on the base-return voltages.

(H. Guckel)

PART II

MATHEMATICAL METHODS

Iterative Solution of Linear Equations (Supported in part by the Office of Naval Research under contract Nonr-1834(27).)

A report has been written summarizing the results obtained in a theoretical and experimental study of some iterative methods for solving linear equations. The title of this report is "The Use of Chebyshev Matrix Polynomials in the Iterative Solution of Linear Equations Compared to the Method of Successive Overrelaxation". An abstract of the report follows:

"The purpose of this investigation is to show the relation between two iterative methods for solving linear equations for which the matrix of coefficients is symmetric, positive definite and possesses property (A) as defined by Young. The first method, the modified Chebyshev method, is a modification of a method derived by von Neumann and Stiefel in which the Chebyshev polynomial of a matrix related to the original matrix of coefficients is used to generate an approximation to the system of linear equations. The second method is the successive overrelaxation method of Young and Frankel.

"For the modified Chebyshev method it is only necessary to use the previous approximant to compute a new approximant, whereas in the original process two approximants are needed to compute a new one. Furthermore, it is shown that to guarantee a fixed accuracy only about half the number of iterations are necessary.

"The iteration formulas for the modified Chebyshev method and successive overrelaxation method are closely related. Indeed, it is shown that on a high speed digital computer under simple assumptions the modified Chebyshev method degenerates into the successive overrelaxation method. In addition, it is shown that to guarantee a fixed accuracy the modified Chebyshev method requires fewer iterations than the successive overrelaxation method.

"The effect of roundoff is considered when the modified Chebyshev method and successive overrelaxation method are used to solve equations on a high speed computer. Bounds are established for the maximum contribution of the roundoff error for both methods.

"A numerical example is given in which the modified Chebyshev method and successive overrelaxation method are used. It is shown that while the

[illegible]

effect of the roundoff is initially small, eventually the analytical results are vitiated by roundoff error. Nevertheless, we conclude that the modified Chebyshev method should be used to solve linear equations for which the matrix of coefficients is symmetric, positive definite and possesses property (A)."

(G. H. Golub)

PART III

SWITCHING CIRCUIT THEORY

(Supported in part by the Office of Naval Research under contract Nonr-1834(27).)

Semi-modular Circuit Theory

A new result relates allowed sequences to lattices of C-states. Let u, $a(1)$, $a(2), \ldots$ be an allowed sequence of states in a circuit which is semi-modular with respect to u. (See Report 75.) Then for any node $i = 1, 2, \ldots, n$, we may construct the corresponding sequence of signals u_i, $a_i(1)$, $a_i(2), \ldots$. This sequence is contracted by replacing identical consecutive pairs by single entries until a sequence u_i, $t_i(1,u)$, $t_i(2,u), \ldots,$ is obtained in which consecutive pairs $t_i(\alpha,u)$, $t_i(\alpha+1,u)$ are always different. It may then be shown that the set of sequences u_i, $t_i(1,u)$, $t_i(2,u), \ldots$ for $i = 1, 2, \ldots, n$ is invariant for all allowed sequences u, $a(1)$, $a(2), \ldots$ starting with u.

As a consequence of the above result we may use the lattice of C-states $L[u]$ and the function $t_i(\alpha,u)$ to characterize the behavior of a semi-modular circuit. Two circuits may be taken as exhibiting identical behavior with respect to two initial states u and v if $L[u] = L[v]$ and $t_i(\alpha,u) \equiv t_i(\alpha,v)$ for all i, α such that $\underline{a}_i = \alpha$ for some C-state $\underline{a}$ in $L[u] = L[v]$.

A further result concerning this representation enables one to obtain $L[a]$ and $t_i(\alpha,a)$ if one is given $L[u]$ and $t_i(\alpha,u)$ and if a lies in an allowed sequence starting with u. In this case $L[a] = \{\underline{x} - \underline{a};\ t(\underline{a},u) = a,\ \underline{x}$ in $L[u]$, and $\underline{x} \geq \underline{a}\}$ and $t_i(\alpha,a) = t_i(\alpha+\underline{a}_i,u)$, where $\underline{a} = (\underline{a}_1, \underline{a}_2, \ldots, \underline{a}_n)$ is a member of $L[u]$ such that $t(\underline{a},u) = \left(t_1(\underline{a}_1,u), t_2(\underline{a}_2,u), \ldots, t_n(\underline{a}_n,u)\right) = a$.

A preliminary result was obtained in the problem of variable discrimination levels. Any semi-modular circuit composed of AND, OR and NOT elements was shown to remain semi-modular if the discrimination levels are made arbitrarily higher on OR elements and arbitrarily lower on AND elements. Extensions of this result apply to more general sets of elements.

A necessary and sufficient condition for distributivity of a semi-modular circuit has been found.

A circuit, semi-modular with respect to "u" is also distributive with respect to "u" if and only if whenever "a" follows "u" and "a", "b", and "a", "c" are single node transition then if a node k is excited in states "b" and "c" it is also excited in "a".

This condition is a state transition condition similar to one which is already known for semi-modularity and should make possible the extension of the notion of distributivity to the more general sets of states to which the notion of semi-modularity has been extended.

(D. E. Muller)

PART IV

ILLIAC USE AND OPERATION

Illiac Library Revision

During the past several months a programmatic revision of the entire Illiac Library has been in progress. All routines in the Active and Auxiliary Libraries were carefully read and checked for latent errors and for exact correspondence between write-ups, standard file tapes, and Teletype Room active tapes. A large number of misprints and miscorrespondences were detected and corrected. These have all been carefully noted so that when each routine is reproduced, they can be incorporated in the distributed copies.

In the future, all write-ups of Illiac programs will explicitly state with which of the input routines (DOI or SADOI, or both) the routine is compatible. All library tapes for use with SADOI have had the directive

OOK (code name of routine)

added at the beginning of the tape. This enables all such tapes to be simply copied onto the user's program tape without additional directive. SADOI will then pack all such library routines and automatically define their first word with the code name of the routine. This procedure does not interfere with the user's placing the routine at any desired place in the memory, since a normal directive,

OOnK,

preceding the aforementioned directive will result in the routine's being placed at location n.

Certain routines were subjected to more extensive revisions. The A6 write-up, Floating Decimal Routine and Auxiliaries, was provided with a listing for both the tape version and the drum version of the routine. F1, Solution of a System of Ordinary Differential Equations, was provided with a rewritten fast SADOI interlude. F2, Solution of a System of Differential Equations by Milne's Method; F5, Integration of a System of Ordinary Differential Equations up to a Specified Value of One Variable; FA2, Floating Decimal Solution of a System of

Ordinary Differential Equations; O5, Fast Character Display 4 x 6 Raster; P5, Print One Number in a Parameter Set Layout; and P12, Single Column Print; were provided with special SADOI interludes. P18, Output for the Dataplotter, and K13, Analysis of Variance by Method of Fitting of Constants, were obsoleted and replaced by P19 and K15 (see below).

(R. H. Flenner and M. T. Gray)

Added Library Routines

A7-244 1.7 Precision Floating Binary Arithmetic and Double Precision Fixed Point Arithmetic With Floating Decimal Conversion (DOI or SADOI). This routine was written as a flexible general purpose double precision routine. It is suitable for problems requiring twelve to twenty-three decimal places of accuracy which do not require a large amount of computing time. The method of interpretation and the interpretive order code are taken almost directly from Illiac library routine A1.

(R. H. Farrell)

07-245 Linear Interpolation for the Cathode Ray Tube (DOI or SADOI). This routine will insert extra linearly interpolated points between computed plotted points on the oscilloscope in order to produce a smoother, more densely plotted graph.

(B. L. Hicks)

M23-246 Closed Eigenvectors and/or Eigenvalues by Jacobi Method (SADOI or DOI). This routine will compute the eigenvalues and the eigenvectors of a real-symmetric matrix of order up to 65. Jacobi's method is used.

(C. C. Farrington)

Auxiliary X13-250 Maximum Speed Sexadecimal Input Preparation (SADOI only). This routine causes any program previously assembled in the Williams Memory, from locations 2 through 998, to be punched out in sexadecimal form, skipping all empty locations. The

output tape, having its own bootstrap, read-in and sum-check program at the front, can be read into the machine without further modification at the maximum speed of the reader in a minimum of time. It can hence be used for inputting long, often-used programs which would be time consuming on SADOI, or for stopping the computer at a convenient point of the calculation (where the contents of A and Q are unimportant) and punching out the Williams Memory, so that the calculations may be resumed at any given time.

(W. W. Lichtenberger)

P19-252 Output for the Dataplotter (DOI or SADOI). This routine replaces P18 which has been obsoleted. It enables the user to plot a series of points with the off-line dataplotter. It facilitates the use of the multiple-symbol feature of that device. In order to conserve punching time, the non-numeric characters in the output of this routine will be held to a minimum.

(C. W. Gear)

Auxiliary E7-253 Simultaneous Integration by Simpson's Rule (DOI or SADOI). This routine is similar to E3 except that two integrals are computed simultaneously.

(D. A. Lehr)

Auxiliary EA1-257 Floating Point Simpson's Rule Integration (SADOI only). This routine uses the Illiac floating-point interpretive routine (A1) code to carry out integration by Simpson's rule.

(D. Hutchinson)

K15-258 Analysis of Variance by Method of Fitting of Constants (SADOI or DOI). This routine uses a method described by Kempthorne, "Design and Analysis of Experiments", page 79. The machine accumulates a sum of squares and cross products matrix from

the observation matrix read in. This matrix is inverted and solved for the various constants. The constants are then printed out along with the inverse matrix for calculation of the standard errors of the constants.

(W. C. Jacob and G. H. Golub)

The Statistical Library

Programs which are of especial interest to persons whose research involves them in statistical operations have been assembled into a new library. This library will be called the Statistical Library.

The programs to be included were developed by persons from several departments of the University. Some were created hastily in response to the needs of a particular research problem. It is for this reason that not all of these programs are in their final stage of development. It is the intention of the Digital Computer Laboratory, in time, to revise any which require improvement and to supply for each program a set of written instructions.

The Statistical Library, when complete, will probably consist of more than 150 programs. Included among them are approximately 20 which are from the Main or Auxiliary Libraries. To enable the user of this library to locate a particular program, a classification system has been devised. To distinguish the Statistical Library from the other computer libraries, each program will be designated by the symbols, KSL, and an index number. For programs which are included in two libraries, both classifications will be used. This is illustrated below:

KSL 1.11	Program 1.11 in the Statistical Library
KSL 2.00, K8	Program 2.00, but also K8 in the Main Library
KSL 2.10, K4 AUX	Program 2.10, but K4 in the Auxiliary Library .

In addition, each routine is assigned a serial number in the same main series which also embraces the Illiac Active Library and the Illiac Auxiliary Library.

The six major divisions of the Statistical Library are as follows:

KSL 1.00 to 1.99	Factor Analysis
KSL 2.00 to 2.99	Indices of Association
KSL 3.00 to 3.99	Analysis of Variance and Covariance

KSL 4.00 to 4.99	Other Statistical Procedures
KSL 5.00 to 5.99	Matrix Operations
KSL 6.00 to 6.99	Useful Algebraic Routines .

Each of these six divisions are further subdivided. Under the classification of factor analysis are eigenvalues and eigenvectors, principal axis solutions, centroid factor analysis, diagonal method of factoring, estimation of communalities, comparisons among factor sets, factor scores, orthogonal rotations of factors, oblique rotation of factors.

Indices of Association includes Pearson product-moments, multiple regression, partial correlations, dichotomous data coefficients, transformations on r's, chi-square, D-statistic, and pattern analysis.

Analysis of Variance and Covariance consists of integrated and general programs, completely randomized design, randomized block design, and rectangular lattice design.

Other Statistical Procedures is a miscellaneous category. It may be divided into two or more categories, at some time in the future, if there are a sufficient number of new routines added to warrant this. At present, it includes frequency distributions, ranked numbers, standard score transformations, construction of random samples, least squares, limited information estimation, and linear programming.

Matrix Operations has been subdivided into the following: multiplication, inversion, addition and subtraction, transposition, deletion and dilation, normalization, summing elements over rows and columns, summing squares of elements by rows and columns, and data-tape checking.

Routines of an algebraic nature are useful at times to statisticians. These are the linear equation solver, finding the roots of a polynomial, and evaluation of a determinant.

An index of these statistical programs has been prepared and duplicated and is available for distribution. This index describes, briefly, each program listed. For those who are interested in the detailed description of the library, it is suggested that they request a copy of the Index of Statistical Programs.

(K. W. Dickman)

KSL 4.00-247 Frequency Distributions (SADOI only). This routine will read sets of n-signed integers and form frequency charts for each set. The lower boundary and the interval between categories are specified by parameters. Alongside the charts will be printed bar graphs. The width of each bar graph is automatically adjusted so as not to exceed the width of the teletype paper. The routine imposes no restrictions.

(K. W. Dickman)

KSL 2.50-248 Fisher's Z Transformation: $Z = \frac{1}{2} \ln \frac{(1+r)}{(1-r)}$ (SADOI only). The chief uses of Z are to be found in problems of averaging correlations and in testing the significance of differences between correlations. The routine will transform any set of signed numbers which are scaled by 10^{-1} to Z values. Whenever a value of Z would be close to positive or negative infinity, these would be bypassed by the routine and indicated by printing a dash. No restrictions are made by this routine.

(K. W. Dickman)

KSL 2.61-249 Chi-square for r by c Frequency Tables (SADOI only). This routine will read any number of frequency tables and print the chi-square value for each table. It will also print the expected values associated with each table if desired. The total frequency for each table must not exceed 1,000,000,000. There are no practical limits for the size of the tables, nor do successive tables need to be the same size.

(K. W. Dickman)

KSL 1.20-251 Centroid Factors with Fixed Communalities (SADOI only). Following the procedures outlined by L. L. Thurstone, this

program will extract centroid factors from a correlation matrix. The program is called fixed to distinguish it from other procedures wherein the communalities are altered during the course of the calculations. The largest matrix that can be factored with this program is one of 111 variables.

(K. W. Dickman)

KSL 2.40-254 Phi's or Covariances for Dichotomous Data (SADOI only). This routine will calculate a matrix of phi's or covariances and the means and standard deviations for dichotomous data. Either a triangular or square matrix may be printed by either rows or columns. In addition, it is possible to calculate and print any submatrix from the total set of intercorrelations. The number of variables is limited to 159, and observations to 2535.

(K. W. Dickman)

KSL 5.57-255 Page Output Correlations (SADOI only). Whenever a matrix is symmetric, both space and computer time are conserved if the matrix is punched onto tape in triangular form. This form is optional output for routines KSL 2.00, 2.01, 2.05, 2.40, and others. The purpose of this routine is to read data in triangular form, and punch it back onto tape in page form. Each row and each column is correctly labeled. There are no practical limitations on the use of this routine.

(K. W. Dickman)

KSL 5.90-256 Data Tape Checking Routine (SADOI only). The purpose of this routine is to check data tapes. The routine will read the first row of a matrix and compare all subsequent rows for number of elements, number of digits in each element, and for the terminating symbol. If there is any disagreement with the first row, the routine will print

the row number and the type of error. This routine will also check in the event that the first row consists of single, unsigned elements. An additional option is that the routine can be used to check triangular matrices. The number of elements in the first row cannot exceed 700.

(K. W. Dickman)

Engineering Library

The Engineering Library is currently being checked and read in order to guarantee that the internal write-ups, the master checking tapes and the engineer's copies of the checking tapes all agree. Some revision of the Engineering Library has been necessary since certain engineering procedures and checking routines are no longer used, and since new procedures and routines have been introduced. In this connection, engineering routines 1, 3, 4, 5, 6, 7, 8, 15, 16, 19, 23 and 27 have been obsoleted, since the corresponding procedures have either been abandoned or modified.

(C. E. Carter and R. H. Flenner)

Engineering Library Routines

C8-47 Machine Time and Error Summation (G. H. Leichner)

C9-48 Transcribe Order Pairs (SADOI only) (G. H. Leichner)

C10-49 Convert Subroutine from SADOI to DOI Form (C. C. Farrington)

D7-50 Reperforate Sexadecimal Characters (DOI or SADOI) (R. H. Flenner)

D8-52 Copy Tape Replacing Space Characters by Carriage Return-Line Feed Characters (R. H. Flenner)

D9-53 Compare Tapes for Sexadecimal Characters Only. (R. H. Flenner)

I8-51 A-B Gate Timing Routine. (W. S. Bartky)

Illiac Usage

During February, specifications were presented for 50 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1289. Numbers followed by T are for theses.

1289 Physics. Resonance Escape. The Monte Carlo method is used to calculate the resonance escape probability of fast neutrons slowing down in an infinite homogeneous mixture of one fuel isotope and one moderator isotope. Initial parameters are chosen randomly according to the physical situation. Input data includes the upper and lower limits of the energy range (E_o, E_f), the masses of the fuel and moderator isotopes (m_f, m_m), the resonance parameters of the fuel isotope, the atomic ratio of moderator and fuel atoms (N_m/N_f), and the temperature of the system (kT). The output consists of the contents of various counters after a specified number of "neutrons" have been considered. Eventually, it is hoped that a library of Monte Carlo routines may be compiled to allow flexible programming of more elaborate systems, including geometry, finite size, more constituents, etc.

Mathematical Method:

1. Random numbers are assumed to be equidistributed over the range $0 \leq r \leq 1$.

2. The initial energy is chosen from:

$$E_o(r) = \frac{E_o}{\left[\frac{2r}{m_m+1} - 1\right]^2} \quad .$$

3. The energy of the fuel or moderator isotope is chosen from a Maxwellian distribution:

$$E_2(r) = kT \cdot x(r), \text{ where } r = \left[1+x(r)\right]e^{-x(r)} \quad .$$

The solution of x(r) is approximated by a polynomial.

4. A random cosine is calculated by a device attributed to von Neumann which consists of "throwing" random points on a quadrant of a circle and using multiple angle formulas to calculate cos $\phi(r)$.

5. The Breit-Wigner formula for the fuel isotope cross section is then solved, using the available, or center of mass, energy

$$E_a = E \cdot \frac{m}{m+1} \left[1 + \frac{E_2}{mE} + 2\cos \phi(r) \sqrt{\frac{E_2}{mE}} \right] .$$

6. The decision of whether the neutron collides with fuel or moderator is made by comparing a random number to the ratio of macroscopic total cross sections.

7. The decision of whether the neutron scatters or is absorbed by the nucleus is made by comparing a random number to the ratio of absorption to total microscopic cross sections.

8. The energy, after scattering, is determined from

$$E' = E \left[\frac{m^2+1}{(m+1)^2} + \frac{2m}{(m+1)^2} \cos \phi(r) \right] .$$

1290 T Agricultural Economics. Effects of Capital on Hog Contracts. The nature of the problem is to see what effects increasing amounts of capital available to the producer will have on the methods of production. The desired objective is to obtain the optimum solution in each case. After the solution is reached, the capital available will be increased to see what is optimum under the new set of conditions. The simplex linear programming method will be used.

1291 T Agricultural Economics. Optimum Farm Program I. The simplex linear programming method will be used to determine optimum farm programs from data furnished by a professional farm manager. A study will be made on the possibilities of the use of linear programming by this group. The possible use of data furnished by farm managers will be considered also.

1292 T Zoology. Ecological Relations of Chickadees. Illiac will be used to evaluate the various factors which determine what environmental factors seem to be correlated with the abundance of two species of birds. The method of least square fitting will be used.

1293 T Civil Engineering. Response of Multi-Degree-of-Freedom Systems to Base Disturbance. Two or more degree-of-freedom systems will be subjected to base disturbances, and their responses will be required. Accelerations of the masses will be assumed; their displacements and velocities will be computed using the Newmark β formulae, and then the accelerations will be computed by summing the forces acting on the masses and dividing these forces by the mass. Assumed and computed values will be compared to determine if assumed values are correct; if not, a new cycle will be computed. At the end of the base disturbance tape, the results will be printed to determine displacements, velocities, etc. Illiac will perform the iterations. Various systems, with various frequencies of free oscillation will be subjected to various types of base disturbance to determine response spectra.

1294 Animal Science. Vitamins in Swine Nutrition. The research problem is concerned with the determination of the minimum dietary level of nicotinic acid, a water-soluble vitamin, required for optimum rate and efficiency of growth in swine. Various levels of nicotinic acid were fed in diets containing varying amounts of yellow corn. The Illiac is used to mathematically determine the minimum level of the vitamin required for optimum performance. The mathematical method is the method of least squares.

1295 T Psychology (Sydney University, Australia). Factors in Morale. There is need for establishing what variables are involved in, and are measures of, industrial morale. This is best approached through factor analyses.

1296 Electrical Engineering. Ring Arrays. A review of the literature on the design of ring arrays reveals some discrepancies in the existing theory. For example, it is frequently stated that it is better to use an odd number of elements in the array if omnidirectional coverage is desired. Calculations show this is not true. Hence, the existing design information is useless. It is proposed to make a systematic study of ring arrays with a view to obtaining design information. The pattern will be calculated from the expression

$$S_N = \sum_{n=0}^{n-1} e^{j\left[n\gamma + k\cos(\phi - n\alpha)\right]}$$

N = no. of antennas in the ring

k = radius of ring in degrees or radians

$$\alpha = \frac{2\pi}{N}$$

$$\gamma = \frac{2\pi m}{N} \qquad m = 0,1,2, \text{etc.}$$

A range of values of k and ϕ will be used. It is also planned to make a few calculations on impedance of each antenna.

1297 Electrical Engineering. Waveguide Step Discontinuities. The problem is to calculate the reflection coefficient due to a step discontinuity in a waveguide. It actually falls into a class of two-region boundary value problems in a waveguide which are being studied in general. It has been found that there is non-uniform convergence and a check is being made on a method developed to find out the correct combination of sets of equations yielding the correct answer. The method is based on the solution of a bifurcation problem in a waveguide for which a similar set of equations result. The bifurcation problem can, however, be solved exactly, for there exists a technique for solving the infinite set of equations. The theory has been checked for this problem with a finite set of equations. For the case of the step discontinuity, however, the infinite equations cannot be solved exactly. The method is, therefore, of use in this case. The check on the method is provided by the behavior of the higher-order coefficients whose asymptotic behavior can be estimated by alternate means.

1298 Agronomy. Reginal Soybean Variety Tests. This involves a new program for analysis of variance of combined experiments. The data are from 56 locations over 3 years. The basic design is a vandomized complete block. The new program will be called "Combined Analysis of Variance for Randomized Complete Block Designs". This project involved about 3,200 analyses of variance problems.

1299 T Psychology. Learning Without Awareness. In an analysis of a study of learning without awareness, several measures of incidental learning have been used. It is hoped that there will be significant correlations between the three measures of primary learning and the nine measures of incidental learning. This can be ascertained from the correlational matrix. Further, it is felt that of the 12 measure taken together, there will emerge several factors which will explain most of the variance. For both the correlational matrix and for the factor analysis Illiac will be of great assistance.

1300 Computer. Tube of Hot Gas. The behavior of a tube of gas heated at one end will be investigated.

1301 Theoretical and Applied Mechanics. Helical-Rail Missile. The equations of motion of the launching system of a helical-rail missile are to be solved by numerical integration. The equations are of the form

$$a_{ij} \ddot{\Theta}_j + b_{ij} \dot{\Theta}_j + c_{ij} \Theta_j + d_i = 0 ,$$

where the a_{ij}, b_{ij}, c_{ij}, and d_i are functions of the $\dot{\Theta}_j$ and Θ_j. Parameters are read in in floating point notation and constants are computed using Al. The rest of the program uses fixed point notation, with Fl to solve the differential equations, and M14 to solve for $\ddot{\Theta}$ at each point. At the end of the calculation, when the missile has left the rail, M19 is used to find the eigenvalues of the free motion.

1302 Theoretical and Applied Mechanics. Launcher Dynamic Study. Eigenvalues of a four-degree-of-freedom linear vibrating system are sought. The coefficient of the characteristic equation are computed and J2 is used to find the roots. The steady state solution is found in terms of two arbitrary parameters by use of a linear equation solver routine written for A5. Basically, the physical problem concerns a rapidly rotating missile spring supported (with damping) in a rigid undercarraige.

1303 Agricultural Economics. Solution of Matrix Equation $Ax = \lambda Bx$ for Largest Eigenvalue and Associate Eigenvector. An attempt is being made to solve the matrix equation, $[A - \lambda B]x = 0$. For the largest eigenvalue and associate eigenvector, A and B are both symmetric.

Method of Solution:

B is inverted and the equation is transformed into $[B^{-1}A - \lambda I|x = 0$. Let $B^{-1}A = Q$. We assume an eigenvector, x_o and form $Qx_o = x_1$, $Qx_1 = x_2$, $Qx_i = x_{i+1}$. Then $\lambda = \frac{x_{i+1}}{x_i}$ after the process has converged, and x_{i+1}, or any multiple, is the desired eigenvector. (The division operation is element by element).

1304 Education. Lower Bound for the Number of Common Factors. The purpose of this problem is to investigate numerically the practical application of a theorem recently proved. This theorem states the greatest lower bound (infimum), for the number of common factors in factor analysis is given by the number of positive latent roots (eigenvalues) of $R - (\text{diag } R^{-1})^{-1}$, where R is the real, symmetric positive definite correlation matrix under consideration. It is hoped to establish definitively what appears to be true from some previous unsystematic work, namely, that this algebraically necessary condition for factor analysis is seldom met in practice. This would seem possible only by running a fairly extensive sampling of representative correlation matrices from the psychological literature.

1305. Education. Paired Comparisons with Missing Data. An analysis for scaling objects by the psychophysical method of paired comparisons when there are large blocks of missing data has been done recently. The solution requires solving simultaneous linear equations where the matrix $\underline{A}$ of the coefficients of the unknowns has the following form: $\underline{a}_{ij} = 0$ or 1, for all $\underline{i}$, $\underline{j}$, $\underline{i} \neq \underline{j}$, $\underline{a}_{ii}$ are chosen such that $\sum_i \underline{a}_{ij} = \sum_j \underline{a}_{ij} = \underline{n}$, where $\underline{n}$ is the order of $\underline{A}$.

There are two distinct aspects of this problem where Illiac could be of use, (1) unfortunately, it has not yet been possible to find sufficient condition(s) for $\underline{A}$ to be non-singular (although it has been possible to establish the necessary condition); consequently, Illiac may be used to settle the number of hunches, (2) in writing a paper about this analysis, it will be necessary to provide an example; rather than restrict $\underline{n}$ to desk calculator size inversions--and thus have only an innocuous illustration--it seeems appropriate to solve a problem large enough to have substantive interest and advertise the usefulness of electronic computers.

1306 T Management. Functional Relationship Between Interest Rate and Investment Level. Illiac will be used to compute a time series measurement of the effect of 4 interest rates on 8 measurements of investment. The time intervals for interest rates range from 12 months prior to investment to 12 months after. Data collected for this study cover the calendar period 1946 through 1957. The K14 program will yield, in addition to the correlations, information which will be used to compute a significant correlation test.

1307 Sociology. Student Attitudes toward Educational Television. The aim of the research is to discover variables which may influence student attitudes toward television presentation of courses at the University of Illinois. Four hundred students in an introductory social science course, half of whom are taking the course by TV lectures, have been tested concerning their attitude toward TV presentation. The problem is to discover factors which are related to the range of response, from approval to disapproval, to TV presentation. The ultimate purpose is to develop some predictive measure as to how students will react to TV presentation. For this reason, multiple regression coefficients will be computed and a factor analysis will be made to see if there are patterns among variables related to student attitudes. Variables to be included are academic grades, attitude toward instructor, experience with instructor, subject matter preferences, occupational aims, social background and adjustment to college life.

1308 Computer. PETITE PILOT. The PETITE PILOT is concerned with the solution of the following minimax problem: given a set of M conditions on the functions $g_i(x_0 \ldots x_{n-1})$, namely

$$G_0 \geq g_0(x_0, x_1 \ldots x_{n-1}) ,$$

$$G_1 \geq g_1(x_0, x_1 \ldots x_{n-1}),$$

$$\vdots$$

$$G_{m-1} \geq g_{m-1}(x_0, x_1 \ldots x_{n-1}) ;$$

it is desired to find values of the variables $x_0^{(0)}, x_1^{(0)}, \ldots, x_{n-1}^{(0)}$ such that the above conditions are satisfied under all variations of the form

$$x_i = x_i^{(0)}(1 \pm \lambda f_i) \qquad (i = 0,1,\ldots,n-1)$$

where $0 \leq f_i < 1$, and λ is as large as possible. This program takes initial estimates of the $x_i^{(0)}$'s and successively corrects them, searching for the point corresponding to maximum λ. An auxiliary program must be provided for calculation of the functions g_i. This program will be used first in an exploratory fashion on an electrical circuit tolerance analysis problem.

1309 T Theoretical and Applied Mechanics. Buckling of Symmetrical Arches. The strain energy of the arch is expressed by $\alpha_{11} A^2 + \alpha_{22} B^2$, where A and B are arbitrary and α_{11} and α_{22} are (volume) integrals of second-order terms in the displacements of the arch and their derivatives. The buckling load is determined as the load for which the quadratic form ceases to be positive definite. The Illiac is to be used to evaluate α_{ii} (1,2) as functions of the load by F5 and determine the first root of $\alpha_{ii} = 0$ (1,2) by H2.

1310 Sociology. Social Cultural Factors in Curricular Choice. The Illiac will be used to compute chi square values to determine the significant level of social cultural variables on curricular choice.

1311 Animal Science. Effects of Egg Yolk, Egg Oil, and Egg Protein on Growth of the Chick. An unidentified growth factor has been reported in egg yolk when added to the diet of the chick. It is believed that this factor may be nothing more than the contribution of fat and protein to the diet by the egg yolk; this series of experiments deals with the testing of this hypothesis. The problem was designed to compare the growth promoting ability of egg yolk, egg oil, and egg white protein when added to the diet of the chick. The Illiac will be used in estimating treatment effects by the method of least squares.

1312 Physics. Cyclotron Phase. The path of a particle in the cyclotron is approximated by a half circle. At the end of each half cycle, an energy increment $\Delta T = \gamma|\cos \omega_0 t|$ is added to the particle's energy; the particle velocity and magnetic field (stored as a function of the radius) determine the radius of curvature for the next half cycle. The phase lag per cycle, $(\Delta \phi)_i$, is given by

$$(\Delta \phi)_i = \pi \left[\gamma_i \frac{B_o}{B_i} - 1 \right]$$

where B_o is the central field, B_i the given field for the i^{th} cycle, and

$$\gamma_i = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} .$$

1313 T Agricultural Economics. An Economic Analysis of Possible Sugar Beet Price Benefits to Ontario Sugar Beet Growers as a Result of Operations of the Ontario Sugar Beet Growers' Marketing Board. The major problem in this study is to discover whether the presence and operation of the Ontario Sugar Beets Growers' Marketing Board has financially benefitted the producers of sugar beets in the province of Ontario.

1314 College of Medicine. Factor Analysis of Some Physiological and Psychological Variables Related to Blood Pressure. Approximately 45 physiological and psychological measurement relating to blood pressure and personality were obtained from normal volunteer subjects. The total population numbered 50. The total group of 50 represents 25 members of Group A and 25 members of Group B. Groups A and B differ in a single important respect. It is hoped that this raw data will yield clearly measurable factors. To that end, Illiac will be used to obtain intercorrelations of the data. These correlations will then be processed to obtain an estimation of communalities to be used in the fixed centroid program. The centroid results will then be analyzed by means of the new oblimax rotation program. The following analysis is desired:

1) a table of intercorrelations for Group A;
2) a table of intercorrelations for Group B;
3) a table of intercorrelations for Group A plus B;
4) means and sigmas for each variable for Groups A, B and A plus B; this step is made so that T tests may subsequently be done;
5) a factor analysis of Groups A and B with an oblimax solution;
6) factor pattern;
7) factor structure with correlations between factors.

1315 Psychology (University of North Carolina). Multivariate Scaling--Jones. It is desired to explore the nature of the relationships among the preferences of ratings from army troops of characteristics of various items of clothing. Methodologically, the problem is concerned with investigating an area of multivariate scaling for establishing the dimensionality of the domain of such ratings.

1316 State Natural History Survey. Correlation of Pheasant Abundance with Soils. Township indices of pheasant populations have been obtained from roadside counts made by rural mail carriers. Each of 1260 townships has been measured for the extent (per cent) of the soil associations occurring in a township. The Illiac will be used to determine, by the method of least squares, the correlation between numbers of pheasants seen per 100 miles of road and the soil associations.

1317 Electrical Engineering. Sound Pressure and Force on Spheres. This problem consists in calculating the force due to a traveling wave ultrasonic field on a small sphere suspended in a barotropic fluid. This force, the solution of a differential equation, has been expressed as an infinite series of terms, each term expressed in Bessel functions of odd and even half-integer order. The Illiac program then consists of calculating a finite number of the aforementioned Bessel functions, suitably forming each term, and finally summing the terms to find the force. The number of terms (hence Bessel functions)calculated depends on the parameters, radius of the sphere and wave length of the sound field. For the irradiation of human and animal patients by ultrasound, accurate knowledge of the force on the sphere is required in order that absolute sound level determinations can be made by the laboratory. Observation of the displacement of a small sphere due to a sound field in a liquid, together with the above calculation of the force necessary for a given displacement, yield the absolute sound intensity of the field.

1318 Electrical Engineering. Human Brain Coordinates. This problem consists of a linear translation and rotation from a set of X-ray coordinates, determined with respect to brain landmarks, to a set of external irradiator coordinates. The purpose of this transformation is to establish the positions of the focus of an ultrasonic multibeam irradiator. Patients are irradiated in the brain in

order to alleviate the tremor and rigidity of Parkinson's disease or other hyperkinetic disorders. Patients suffering from intractable pain (thalamic, amputation stump and post-herpetic) also undergo this treatment. Since the surgery and irradiation procedures are carried out in Iowa City, Iowa, soon after the X-rays are taken, it will sometimes be necessary to run the Illiac answer tape through Illiac (a second program) in order to translate the coordinate transformation answer tape into Bell teletype TWX for transmission to the Iowa City Hospital in time for the operative procedure.

1319 Agricultural Economics. Study of Religious Beliefs. The religious beliefs of rural people in a specific denomination are being studied to see to what extent these beliefs agree with the denominational teaching. Illiac can be used to calculate whether there is any significant differences in the beliefs of different categories of denomination members.

1320 Chemistry. Calculation of Energies of the System ($H + H_2$). From the results of the statistical computation of Reaction Probabilities for the system $H + H_2$, calculate: Kinetic Energy of Translation, Kinetic Energy of Rotation, Kinetic and Potential Energies of Vibration, Hamiltonian, Angular Momenta. Potential Energy is calculated by means of the Morse Equation, which involves exponential functions; the remaining calculations consist merely of algebraic expressions.

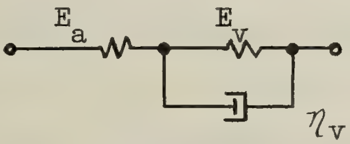
1321 Computer. Computation of Bounds for the Error Vector of Several Methods of Solving Linear Equations. This program was written to compute the bounds of the error vector for three iterative methods which are used for solving linear equations. Two of the iterative methods are variations of the successive overrelaxation method of D. Young, and the third method uses Chebyshev polynomials.

1322 Electrical Engineering. Cylindrical, Spherical and Paraboloidal Sound Focusing Surfaces. This problem consists in calculating the distribtuion for pressure of focused sound fields of spherical or cylindrical lenses and/or paraboloidal reflectors. To do this, Illiac will integrate the incremental pressure at a point in the sound field over the face of the sound source; then repeat the process at a new point. Twenty or thirty of such pressure calculation depict the pressure

distribution (usually axially) of a particular sound source. The subroutine for F5 is changed to correspond to calculation of the incremental pressure in cylindrical, spherical, or parabolic coordinates as the case may be. The object of this program is to determine what shape sound focusing surface will produce the most intense and/or uniform sound field for irradiation of humans and animals.

1323 Electrical Engineering. Transmission Coefficient. This problem consists in the calculation of the sound transmission coefficient for a system consisting of a crystal emitter and lens, focusing sound into water. The lens and crystals are separated by a gap filled with water or castor oil; therefore, this is a four-medium, three-interfact transmission problem. The transmission coefficient has been expressed as a function of several terms containing the parameters, distance between lens and crystal, wave length of the sound, thickness of the lens, and acoustic impedance of the lens. Illiac will compute the transmission coefficients for the variable of lens thickness and will integrate to form the total transmission coefficient. The results of this computation for several different acoustic impedance materials will yield information relative to the best lens materials to be investigated experimentally.

1324 Civil Engineering. Ground Shock Transmission in a One-Dimensional Soil Model. The problem is primarily one of performing a numerical integration which is employed in determining the soil stress at any particular depth and time for a shock applied to a one-dimensional soil model.



$\eta_v = \mathcal{T} E_v$

Model of Equivalent Spring and Dashpot System

For the above model, which was chosen to exhibit basic characteristics of a one-dimensional (continuous) medium, the stress-strain relationship is of the following form:

$$\frac{\sigma}{E_c} + \frac{\mathcal{T}}{E_a}\frac{\partial \sigma}{\partial t} = \epsilon + \mathcal{T}\frac{\partial \epsilon}{\partial t}$$

where $E_c = \dfrac{1}{\left(\dfrac{1}{E_a} + \dfrac{1}{E_v}\right)}$, σ = stress, $\mathcal{T} = \dfrac{\eta}{E_v}$ = retardation time,

ϵ = strain = $\frac{\partial u}{\partial x}$, and u = displacement of the soil column. From dynamic equilibrium equations of the soil column, a single equation may be found in σ so that ϵ is eliminated. A basic solution $\sigma = Ae^{i\omega t} e^{-i(f+ai)x}$ is assumed for σ and expressions for f and a, in the solution for σ, are found in terms of ω, E_c, E_a, η , and f, the soil density; f and a must be known for each iteration, i.e., these two quantities must be known for each numerical integration of the expression which gives stress increments to be superposed at a particular depth and time. For particular depths, stress histories are to be computed, i.e., time-stress curves for particular depths of a given soil are to be obtained. The study is to be made to determine the effect of variation of soil properties on the stress histories and to determine the range of applicability of the solution with the type of soil model being used. The shock can be expressed in a Fourier integral for which the numerical solution involving superposition has been developed; the Illiac can be used to perform this numerical integration, and generate the constants, i.e., frequency, phase, decay coefficients, etc., which are necessary to determine each increment of stress.

1325 Zoology. Osteometric. From skeleton measurements the mean, standard deviation, coefficient of variation, and the coefficient of correlation are obtained. Although the standard library routines could have been used much more, it was felt that the experience gained by programming some of the calculation would compensate for the additional effort.

1326 Structural Research. Numerical Integration of the Equations of Motion of a Generalized Dynamical System. In this investigation the solution of the equations of motion of the general undamped, N-dimensional linear system is being programmed for Illiac. The solution is carried out by a combination of matrix algebra and numerical integration techniques. When viewed in matrix notation, the equation of motion, like the form,

$$[m] \{\ddot{x}\} + [S] \{x\} = \{P(t)\}$$

where $[M]$, $[S]$ and $\{P(t)\}$ are, respectively, the mass, stiffness and forcing function matrices of the system. Since the motion of any undamped linear system can be reduced to this form, the program to solve this matrix equation will have wide application in dynamical analysis. At present the case of an elastic beam subjected to blast type of loading is being programmed.

1327 Structural Research. Inelastic Shell Response. This problem is similar in purpose to problem 1114. The object is to obtain time histories of stress and displacement when subjecting a spherical shell to blast loadings. The mathematical procedure used is essentially a series of relaxations of initially assumed distortion configurations. The relaxation procedure distributes incompatible distortion shapes until both states and dynamic equilibrium are achieved. The procedure marches along in time for "n" steps, where n is the number of time increments into which the blast pulse is divided. Each one of the n steps requires roughly three to four relaxations before equilibrium is achieved. Unfortunately, n must be quite large for this investigation so the program is written in such a fashion that the operator may run the program in parts. A white switch option enables the operator to punch out all necessary data in a form compatible with SADOI so that it may be reread at the operator's convenience. The problem differs from 1114 in that the material investigated has nonlinear properties. The inelasticity considered complicates the problem to the extent that roughly 4,000 words of drum storage plus the WM are the minimum required space. A contemplated modification will raise this to 5,500 drum locations.

1328 T Marketing. Expenditures of the Aged. This program examines the influences upon expenditures of two age groups of consumers (55 to 64 and 65 and over). Library routine K14 will be used to compute multiple regressions.

1329 Chemistry. Fitting Chemical Data. Occasionally it is desired to fit laboratory or literature data to some empirical expressions, using least squares or some similar standard method. For example, one might look for particular correlations of bond energies with measures of bond distances. Library routines K3, L2, L3 and perhaps additional auxiliaries will be used for this purpose.

1330 Physics. Klein Gordon Phase Shifts and Scattering Cross Sections. The cross sections for Klein Gordon particles (K^- mesons) scattered from a complex potential well ($V = V_r + iW(r)$) will be calculated. This will be done by means of a phase shift analysis.

1331 Psychology. Study of Problems in Time Series Factor Analysis.

1. Rotation of three factor matrices of physiological data taken from treatment of prostatic cancer patient.

2. Possible: correlation and factor analysis of data on a second patient.

3. Exploration of above physiological variables for serial correlation (autocorrelation).

4. Construction and factoring of artificial time series in order to test theories about the role of trend and autocorrelation in time series data.

1332 Civil Engineering. Buckling of Buried Arch. The problem involves the determination of the deflected shape of a flexible arch under load. This involves the solution of a set of linear equations for many stages in the loading. Starting with an undeflected arch, add an increment of load and find the new shape. Using this deflected shape, add another increment, etc. Small increments are used to linearize a set of transcendental equations so that $\sin \theta = \theta$ and $\cos \theta = 1$, etc. The main variable will be the number of equations and the stiffness of the arch itself.

1333 T Economics. Parameter Estimation and Forecasting. One Hundred and twenty samples of 25 observations each have been taken. The data has been constructed using specified means and variances; parameter estimates have been made by least squares and limited information single equation approaches. The task is to make forecasts and statistically test the results. Because of the number of samples and observations per sample the problem would be practically impossible without using Illiac. Briefly, the forecasting is done by solving two equations in two unknowns 6,000 times (60 of the samples, 2 models, 2 estimating techniques); an F test of significant differences of variances due to the use of different estimating techniques is made; a student's t test of mean differences is used; a V test of significant differences in variance-covariance matrices is computed using Wilk's Λ criterion.

1334 T Animal Science. Luteotrophin in Swine. This problem is an attempt to determine the effect of a hormone (prolactin) on the reproductive processes in swine. The data that has been collected is confounded by (a) hormonal treatments; (b) time of autopsy (stages) and (c) dates of beginning injections. The program selected (K-14) can best render a statistical analysis of the variables according to the method of least squares.

1335 Education. Training Children in Scientific Inquiry. This problem is a test of an experimental training method for improving scientific inquiry in children. Two groups were trained by variations of the new method and a third was a control. The performance of each subject on a test of inquiry skill (given at the end of the training period) was rated by five judges. Group differences in performance will indicate effectiveness of training. Illiac will be used to evaluate treatment effects by the method of least squares.

1336 Institute of Communications Research. Study of TAM Television Teaching. The purpose of this study is to examine the effectiveness of, and attitudes toward, closed-circuit television teaching. An experimental group (taking a TAM course via closed-circuit television) and a control group (taking the same course via conventional lecturer) were tested. The analysis will require the obtaining of $\bar{v}$ and σ for each of 106 variables for the two groups.

1337 Veterinary Medicine. The Effect of Distemper Serum and Vaccine on Dogs. This problem involves the analysis of the data obtained from dogs. The data are the values of serum proteins after canine distemper serum administration, and after canine distemper vaccination. The mathematical analysis is by the method of least squares.

1338 T Mathematics. A Computation of Binomial Probabilities. Illiac will be used to carry out several calculations in connection with studies aimed at establishing methods to determine the confidence interval for the median of a given distribution.

Table I shows the distribution of Illiac machine time for the month of February.

TABLE I

	Hrs:Min	
Regular Maintenance	18:40	
Unscheduled Maintenance	10:40	
Drum Engineering	27:29	
Leapfrog	31:39	
R.A.R.	3:38	
Library Development	4:44	
Wasted	:00	
		96:50

<u>Use</u> <u>by</u> <u>Departments</u>

Computer	58:31		
Physics	20:39		
Control Systems Laboratory	55:25		
Structural Research	52:45		
Structural Research (AF 464)	17:26		
Civil Engineering (A.A.S.H.O. Road Test)	2:34		
Psychology	30:25		
Education	3:28		
Electrical Engineering	13:14		
Elect. Eng. (AF 6079)	:43		
Elect. Eng. (NOBSR 64723)	:14		
Elect. Eng. (BOEING)	:51		
Sociology	6:25		
Chemistry	73:24		
Agriculture	23:40		
Inst. of Com. Res.	:17		
Inst. of Com. Res. (9067C)	4:51		
College of Medicine	:54		
Bureau of Educational Research	4:34		
Theor. and Appl. Mechanics (ORD 593 IC)	7:03		
Economics	3:30		
Economics (NSF)	:40		
Mech. Eng. (ORD 1980)	:13		
Min. and Met. Eng. (AF 3789)	:12		
State Department of Public Welfare (1715)	2:48		
State Water Survey	2:54		
State Water Survey (SC 75055)	1:17		
Michael Reese Hospital, Chicago, Illinois	:16		
Eastern Illinois University (Botany)	1:12		
University of North Carolina	:02		
Demonstrations	:23		
Miscellaneous	10:49		
		402:39	
			499:29

Error Frequency and Analysis

The Illiac is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, for an error standpoint, to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared, using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked), if no errors are found, the time is given to the "running column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for February.

TABLE III

Williams Memory	2
Arithmetic	2
Control	1
Drum	10
Input	2
Punch	2
Engineer Error	1
Unknown	1
Total	21

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	SCHEDULED ENGINEERING	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/2/59	22:56	:00	0		1:04	:00	1:12	0
2/3/59	21:04	1:33	2	(1) Input-Output error (2) Unknown	1:23	:00	1:35	1
2/4/59	21:51	:00	0		2:09	:00	1:10	0
2/5/59	22:30	:00	0		1:30	:00	1:10	0
2/6/59	20:26	1:48	2	(1) Input error (2) Williams Memory error 2^{-12}	1:46	:00	:54	0
2/9/59	21:57	:00	0		2:03	:00	1:07	0
2/10/59	21:53	:00	0		2:07	:00	1:41	0
2/11/59	21:38	:01	1	(1) Drum failure	2:21	:00	1:03	0
2/12/59	20:56	:01	1	(1) Punch error, Punch # 5	3:03	:00	1:00	0
2/13/59	23:02	:02	2	(1) Drum failure (2) Drum failure	:56	:00	1:30	0
2/16/59	21:05	:27	2	(1) Punch error, Punch # 5 (2) Drum failure	2:28	:00	1:01	0
2/17/59	21:23	:01	1	(1) Drum failure	2:36	:00	1:00	0
2/18/59	16:51	3:57	2	(1) Drum failure (2) Arithmetic error, 2^{-39} of adder	3:12	:00	:20	0
2/19/59	22:53	:02	2	(1) Drum failure (2) Drum failure	1:05	:00	:41	0
2/20/59	21:46	:25	1	(1) Drum failure	1:49	:00	1:03	0
2/23/59	20:24	1:00	1	(1) Engineer's error	2:36	:00	1:27	1
2/24/59	18:37	:43	2	(1) Williams Memory error 2^{-30} (2) Control error	4:40	:00	1:00	0
2/25/59	21:24	1:01	1	(1) Arithmetic error 2^{-39} adder	1:35	:00	1:07	0

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	SCHEDULED ENGINEERING	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
2/26/59	18:31	2:28	1	(1) Drum failure	3:01	:00	:41	0
2/27/59	22:28	:00	0		1:32	:00	:43	0
TOTALS	423:35	13:29	21		42:56	:00	21:25	2

PART V

IBM 650 USE AND OPERATION

Introduction

On January 26, 1959, a medium-speed Magnetic Drum Data Processing System, Model No. 650, arrived on a rental basis from the International Business Machines Corporation. The system, installed in Room 157, Engineering Research Laboratory, with auxiliary equipment in Room 161, was assembled and tested and became available to the Digital Computer Laboratory on February 9.

The air conditioning equipment for this installation has not yet arrived, but, in spite of this, the machine was placed in limited operation during the remainder of February. It was capable of being utilized approximately 3 hours out of the 9-hour shift, which is to be the initial working day of the machine.

The system consists of:

one 650 console and magnetic drum unit
one 655 power unit
one 533 card read punch
one 653 high-speed storage, floating point, index registers
one 652 tape control unit
two 727 tape units
one 407 accounting machine.

The 407 accounting machine may be used on-line with the 650 computer. The input and output units of the system are provided with the appropriate additional equipment which allows alphabetic characters to be input and output.

This system is supported by the following auxiliary equipment:

two 026 key punches
one 056 verifier
one 082 sorter
one 514 reproducer .

This machine was obtained in order to relieve the Illiac from those calculations which are input-output dominated. Although the internal computation

speed of this system is slower than Illiac by some factor between 50 and 100, its input-output speed for some types of problems can be as much as 5 times faster. The Business Office of the University will have access to the machine to ultimately carry out such administrative tasks as inventory, student records, payroll, etc. The machine will also participate in the research and instructional program of the University. It will be used as an integral part of a new course offered by the Digital Computer Laboratory, Math. 295, Introduction to the Use of Digital Computers.

In general, the policies with respect to the availability of this machine and its use will be similar to those in effect for the past seven years with respect to Illiac. The only formal requirement will be the submittal of a request for a problem specification number. These problem specification numbers will be assigned serially, but designated by a prime. Abstracts of these problem specification number requests will be published in these monthly reports.

A library of routines for use with the IBM 650 System will be maintained in the Digital Computer Laboratory. This library will consist of two parts--first, a large selection of routines obtained from other installations; these will be kept on file and will be available on request; second, a working library, called the Digital Computer Laboratory IBM 650 Library, will be constructed with more readily available decks and write-ups available for distribution. The format of these write-ups will be similar to that in the Illiac Library. The library routines will be classified according to the scheme set up by Internal Report No. 55 of the Digital Computer Laboratory. Each routine will be given such a code name, and, in addition, a serial number. Both of these will be distinguished by a prime to avoid confusion with the Illiac Library. This classification is as follows:

IBM 650 Library Categories

<u>Programmed Arithmetic</u>

A' Floating Point

B' Other programmed arithmetic

Code Checking

C' Post Mortem checks

D' Dynamic code checks

Integration

E' Quadrature

F' Ordinary differential equations

G' Partial differential equations

Operations on Functions

H' Zeros and minima

I' Interpolation

J' Operations on polynomials and power series

K' Approximations and statistics

Linear Algebra

L' Simultaneous linear equations

M' Other operations on matrices and vectors

Input and Output

N' Number input

O' Scope output

P' Printing and punching

Mathematical Logic

Q' Mathematical logic

Particular Functions

R' Roots and fractional powers

S' Logarithmic, exponential and hyperbolic functions

T' Trigonometrical functions

V' Other special functions

Organizational

W' Counting, sorting and selecting

X' Program preparation

Miscellaneous

Z' Miscellaneous complete programs

At present the Active Library is being drawn from selected portions of available 650 Libraries from other installations. These are picked and recast into the Digital Computer Laboratory format.

IBM 650 Library Routines

X1'-1' Load One to Seven Words Per Card From the 533 unit. This routine reads an arbitrary number of words (up to 7 per card) from cards.

X2'-2' Load One Word Per Card.

X3'-3' Clear the Drum to + zeroes. This program is to be used initially to clear the drum.

X4'-4' Clear the Drum to - zeroes. This program is to be used initially to clear the drum.

C1'-5' Load Stops Program. This routine initially labels each drum location with a stop order marked with an address equivalent to its location.

R1'-6' Floating Point Square Root. This routine computes the square root of a number in the floating-point mode of operation.

P1'-7' Punch One to Seven Words Per Card From the Drum as Specified by the Programmer. This routine punches a program or data from the drum onto cards. It may be entered either from a program or from the console. The latter facility enables it to be used as a dumping routine.

S1'-8' Floating Point Natural Logarithm. This routine computes the natural logarithm of a number in the floating-point mode of operation of the machine.

T1'-9' Floating Point Arctangent Subroutine. This routine computes the arctangent of a number in the floating-point mode of operation of the machine.

S2'-10'' Floating Point Exponential. This routine computes the exponential of a number in the floating-point mode of operation of the machine.

R2'-11' Fixed Point Square Root. This routine computes the square root of a number in the fixed-point mode of operation of the machine.

T2'-12' Floating Point Sine and Cosine. This routine computes either the sine or the cosine of a number in the floating-point mode of operation of the machine.

A Description of the Digital Computer Laboratory Standard 407 Control Panels.

(R. H. Flenner, M. T. Gray and K. E. Shannon)

IBM 650 Usage

During February, specifications were presented for seven problems.

1' Statistical Service Unit. Product-Moment Correlation Routine. A new program to compute product-moment correlations on incomplete data is to be written. This program will be frequently used in order to improve calculations which are at present often done on the 604 calculator.

2' State Water Survey. Raindrop Analysis. Photographs of raindrops were taken, during thunderstorms, at one-minute intervals by means of radar equipment. From the photographs, the horizontal and vertical diameter of each raindrop was recorded. The IBM 650 is to be used to:

1. compute the average diameter of each drop, $d = \frac{h+v}{2}$;
2. compute a frequency distribution on raindrop size for each minute's data;
3. compute five totals or factors, such as volume of water, from the frequency distribution; each total is of the form

$$T_1 = \sum_{i=1}^{i=n} f_i K_i$$

where n = number of intervals in frequency distribution.
f_i = any of the frequency cells
K_i = a constant to be applied to f_i .

3' Civil Engineering. Design of Bridge Truss. The routine will design any of six different kinds of trusses, (Howe, Pratt, Warren) either deck loaded or "through type", for any curved chord heights, and for any wheel or uniform moving loads or dead load. The production of successive influence lines will be produced and utilized to determine stresses and, finally, areas.

4' Civil Engineering. Influence Lines for Simple Beams. This is the first machine problem for CE 293-493 (Computer applications in Civil Engineering). It involves the computation of shears and moments at specified points along the beam

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

as a unit load moves from one end of the beam to another. The problem consists of the repeated evaluation of two simple functions as the variable is stepped up by successive increments. Tests are included to modify the functions when the critical value of the variable has been reached and to detect the end of the problem.

5' Statistical Service Unit. Statistical Service Unit Instruction and Demonstration. It is desired to code check the programs which were written, as practice problems, by members of the Statistical Service Unit. These programs are not intended to be used in solving specific problems, but only as a training aid to the programmers who wrote them. None of the programs will require extensive 650 time since they are, by design, simple programs suited to beginning programmers.

6' Dairy Science. Analysis of Lactation Records. Sums and sums of products on thirteen measurements of body types and production records of dairy cows are to be computed. IBM 650 time will be required to alter and test an existing program to assure that an analysis of variance can be computed from the output. After the program has been tested, a total of some 5,000 records will be processed.

7' Statistical Service Unit. University Stores Inventory. Computer methods of perpetual inventory of the various university storerooms and the billing procedures involved in charging materials to departments will be developed. The annual physical inventory weekly stock status report and the quarterly report stock status physical inventory report will be processed by the computer.

Table I' shows the distribution of the IBM 650 machine time for the month of February.

TABLE I'

	Hrs:Min		
Regular Maintenance	6:40		
Unscheduled Maintenance	7:59		
Library Development	8:26		
Instruction	10:00		
Wasted*	87:28		
		120:33	
Use by Departments			
Statistical Service Unit	8:05		
Structural Research	5:47		
Classes	:35		
		14:27	
			135:00

* This excessive wastage was occasioned by enforced cooling periods due to the lack of air conditioning.

Error Frequency and Analysis

The IBM 650 is normally on from 8 a.m. to 5 p.m. The machine is used for preventive maintenance from 8 a.m. to 12 noon on Tuesdays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance. It should be noted that the excessive wastage during the month of February was occasioned by the necessity of turning the machine off for approximately two hours after each one-hour running period to permit it to cool.

Table III' presents a summary of errors for February.

TABLE III'

727 and 533	1
533	3
IAS	2
Total	6

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED*	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
2/9/59	2:42	:00	:00	6:18	0	
2/10/59	4:00	:00	:00	5:00	0	
2/11/59	4:06	:00	:00	4:54	0	
2/12/59	:15	:00	:00	8:45	0	
2/13/59	3:25	:00	:00	5:35	0	
2/16/59	3;03	:00	:30	5:27	1	(1) 727 not connected and 533 cover loose
2/17/59	2:24	1:32	:10	4:54	1	(1) Several heads for the control panel were bent
2/18/59	1:19	1:38	:00	6:03	0	
2/19/59	2:30	:00	:06	6:24	1	(1) 533 card lever on read side needed adjustment
2/20/59	1:45	:00	:00	7:15	0	
2/23/59	2:42	:00	:07	6:11	1	(1) Halt switch on read side of 533 needed replacing
2/24/59	:54	3:30	:00	4:36	0	
2/25/59	1:44	:00	:00	7:16	0	
2/26/59	1:47	:00	:00	7:13	0	
2/27/59	:17	:00	7:06	1:37	2	(1) IAS working improperly (2) IAS working improperly
TOTALS	32:53	6:40	7:59	87:28	6	

* This excessive wastage was occasioned by enforced cooling periods due to lack of air conditioning.

PART VI

GENERAL LABORATORY INFORMATION

Reports and Seminars

Seminars

"The Relevance of the Perron-Frobenius Theory of Non-negative Matrices to the Numerical Solution of Simultaneous Linear Equations", by Dr. Richard S. Varga, Bettis Atomic Power Div., Westinghouse Electric Corp., Pittsburgh, Pennsylvania, February 9.

"Elimination of Carry Propagation in Digital Computers", by Dr. G. A. Metze, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, February 16.

"The Description of Finite Sequential Processes", by Dr. Kenneth E. Iverson, Computation Laboratory, Harvard University, Cambridge, Massachusetts, February 23.

Personnel

The personnel associated with the department and, hence, the contributors to this report are:

Bahls, James E., Jr. Laboratory Mechanic
Baur, John W., 1/2-time Research Assistant (Started Feb. 1)
Beardwood, Miss Jillian E., 1/2-time Research Assistant
Bivins, Robert L., 1/2-time Research Assistant (Started Feb. 1)
Blencoe, Robert W., Computer Operator I
Bowes, Mrs. Doris E., 1/2-time Research Assistant
Buenger, George E., 1/2-time Research Assistant
Carter, Clifford E., Electronics Engineer for Illiac
Chow, Yuan S., Research Associate
Clark, Miss Helen B., Secretary
Cummins, Richard L., Research Assistant
Dickman, Kern W., Research Assistant
Ellsworth, Mrs. Jean E., Clerk-Stenographer II
Fileccia, John L., Electronics Technician I
Flenner, Ross H., 1/2-time Research Assistant
Fosdick, Lloyd D., Res. Asst. Prof. of Physics
Foster, Merlin J., Computer Operator I
Foulk, Clinton R., 1/2-time Research Assistant
Gear, Charles W., 1/2-time Research Assistant
Gillies, Donald B., Res. Asst. Prof. of Appl. Math.
Gray, Mrs. Mary T., Research Assistant
Guckel, Henry, 1/2-time Research Assistant
Gustafson, Ronald A., Electronics Technician I
Halton, John H., 1/2-time Research Assistant

Huffman, W. Logan, Computer Operator II
Hunt, Miss Rosalie J., Tab. Machine Operator I (Started Feb. 16)
Johnson, Noel H., 3/4-time Research Assistant
Kerkering, Thomas E., Sr. Laboratory Mechanic
Krabbe, Shirlie P., Electronics Technician II for Illiac
Handscomb, David C., 1/2-time Research Assistant
Leslie, James D., 1/2-time Research Assistant
Lindquist, A. Bruce, 1/2-time Research Assistant
Liu, Chao-ning, 1/2-time Research Assistant
Lopeman, Harold E., Electronics Engineer
Marcer, Peter J., 1/2-time Research Assistant
Meagher, R. E., Head of the Laboratory
Metze, Gernot A., Research Associate
Michael, George W., Administrative Assistant
Minn, Hokee, 1/2-time Research Assistant
Muerle, John L., 3/4-time Research Assistant
Muller, David E., Res. Assoc. Prof. of Appl. Math.
Murrell, T. A., Assoc. Prof. of Elec. Eng.
Naikelis, U. Stanley, 1/2-time Assistant (Started Feb.1)
Oare, John W., Draftsman
Pelg, Edmund, Electronics Technician I
Penny, Samuel J., 1/2-time Research Assistant
Piper, Thomas C., 1/2-time Research Assistant (Started Feb. 1)
Poppelbaum, W. J., Res. Asst. Prof. of Elec. Eng.
Purcell, Kenneth G., Jr. Laboratory Mechanic
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Ray, Sylvian R., 1/2-time Research Assistant
Richardson, Warren V., Office Machines Tech. I
Robertson, James E., Res. Assoc. Prof. of Elec. Eng.
Rosenkrantz, Walter A., 1/2-time Research Assistant
Rudman, Mrs. Linda G., Computer Teletype Operator
Russell, Miss Ramona J., Computer Operator II
Schleifer, Martin N., 1/2-time Research Assistant
Serio, Frank P., Electronics Technician I
Shannon, Mrs. Katherine K., 1/2-time Research Assistant
Shelly, James H., 3/4-time Research Assistant
Shively, Richard R., 1/2-time Research Assistant (Started Feb. 1)
Snyder, James N., Res. Prof. of Physics
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Lenoir, S. Paine, Jr.

The Department Advisory Committee consists of Professors L. D. Fosdick, D. B. Gillies, D. E. Muller, W. J. Poppelbaum, J. E. Robertson, J. N. Snyder and A. H. Taub.

Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - MATHEMATICAL METHODS

PART III - ILLIAC USE AND OPERATION

PART IV - IBM 650 USE AND OPERATION

PART V - GENERAL LABORATORY INFORMATION

March, 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The Rich Electronic Computer Center at Georgia Institute of Technology is participating in this work by the support of a staff member at the University of Illinois.

1. Shifting Register Test Unit

During March an errorfree run lasting 279.4 hours was stopped by causes which could not be ascribed to a particular transistor or diode. One tap-sensitive transistor and three shorted diodes were found. In general, gate 1 and gate 5 pulses were sensitive to variations in the -4v supply. Two transistors with high V_{EB} forward and a diode with low reverse voltage were found in the gates. It was also found that several transistors (one with high V_{EB} forward, two with V_{EB} reverse, and five which satisfied the testing criteria) loaded the gate driver for gate 4 such that proper operation became questionable, especially when the -4v supply dropped to -3.8v.

(G. Metze)

2. Basic Circuits

Following the redesign of the basic circuits to accommodate the new type S577G Transitron diodes, attention was directed toward the design of a number of special circuits. In particular, a new design was obtained for a base 4 adder which uses 20 transistors and 93 diodes. The adder circuit is completely tolerance analyzed. It has a maximum spread through its longest path of 1.35 volts. This allows the use of at least one additional stage of logic, for instance, a switch to enable each output of the adder to be gated to either of two places.

(N. E. Wiseman)

In order to alleviate the problem of cascading many levels of logic between two registers, a so-called "selector" has been designed. Figure 1 shows the principle. The ordinary output emitter-follower of a restoring circuit (in

[illegible]

[illegible]

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[illegible]

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[illegible]

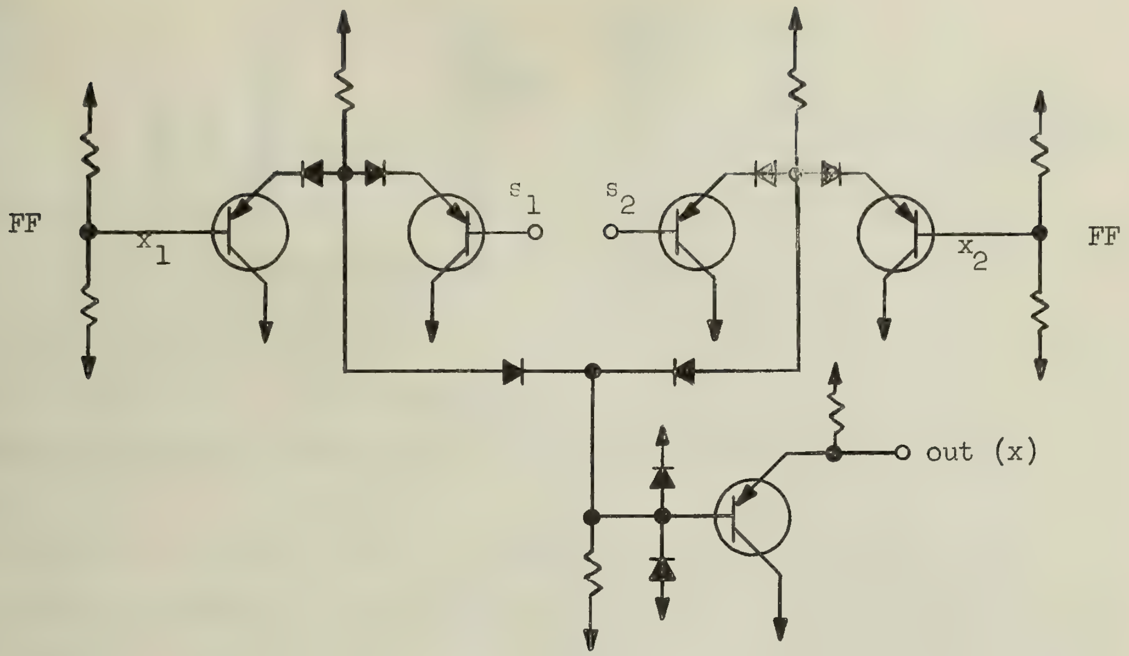

Figure 1

Selector. $x = s_1 x_1 \vee s_2 x_2 \vee \ldots$

particular, a flipflop) is made part of a high-swing AND gate, the other input of which is controlled by a high-swing driver. It is essential that the two input swings available be larger than the normal output swing of restoring circuits. The dc-drop compensating diodes are used to form a multiple OR, the output of which is standardized by bumping diodes and fed into an emitter-follower. Visibly such an arrangement allows one to obtain register selection without using up the available cascading factor.

(W. J. Poppelbaum)

Considerable revision of the flow-gating circuits was necessary in order to reduce the number of non-standard supply voltages. A 3-register 12-bit test unit is nearly completed and performance figures will be available shortly.

(H. Guckel)

In order to simplify diode speed tests, experiments were started to measure the "intrinsic time constant" τ_0 of diodes defined by charge stored = forward current x τ_0. Figure 2 shows the circuit designed to measure τ_0 directly; D_1 and D_2 are two diodes with similar forward and reverse behavior. The diode to be

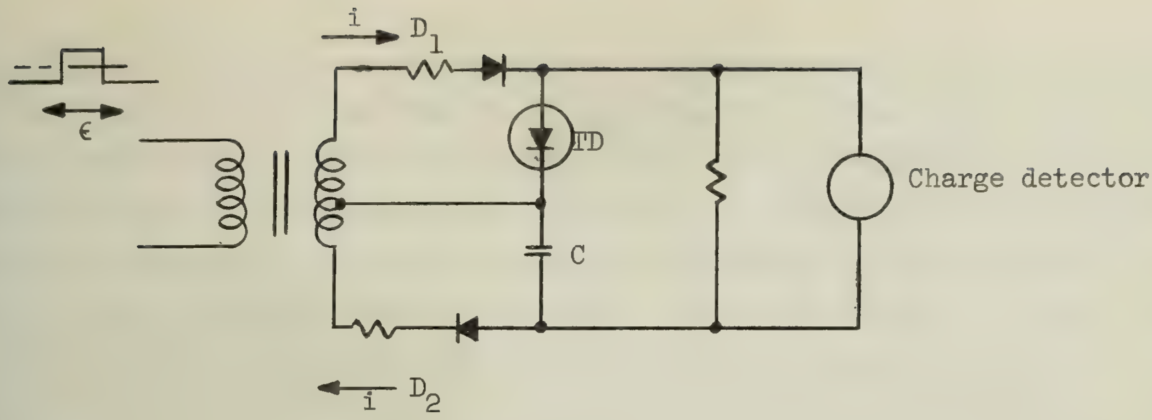

Figure 2

Test Equipment to Measure the Intrinsic Time Constant of Diodes

tested (TD) receives in a cycle, which is long compared to t or $\mathcal{T}_o$, a charge $Q_1 = i\mathcal{T}_o$, while the capacitor C receives $Q_2 = it$. When t is adjusted to be $= \mathcal{T}_o$, $Q_1 = Q_2$, and the charge detector indicates no net charge after the pulse has decayed.

(G. E. Buenger and W. J. Poppelbaum)

The single divider synthesis program (1250) described in the November, 1958, Progress Report was modified to provide a sequential examination of the variables in two (decimal) digit discrete steps. This program turns out to be a very useful tool. It is proposed to write similar programs for circuits of slightly increased complexity.

(N. E. Wiseman)

3. Core Memory

The investigation of the proposed arrangement and driving of the core memory continued throughout March. With regard to rewrite ("B") drivers, it was found experimentally that the propagation time of a signal through 2048 words (4096 cores and 27 feet of wire) is some three to four times slower than was originally allowed for when a 3-wire bundle (2 B-wires and 1 sense wire) is used. The delay time is as follows:

	Number of wires in Rewrite-Sense group		
	3	2	1
Propagation time through 2048 words (4096 cores on 27 feet of wire)	230 mμs	180 mμs	70 mμs

The error which was made in extrapolation from the measurements (for one wire only) made earlier (File No. 251) was that of not allowing for the additional capacitance of wires to one another. Another difficulty which was found is that for any number of rewrite and sense wires greater than one, even with properly matched terminations at both ends of each wire, the time required for the rewrite driver turn-off transient to settle is twice the delay time down the wire. Thus, for example, for 2048 words and a 3-wire rewrite-sense group, the settling time to be allowed at the end of a memory cycle would be about 460 mμs. It has, therefore, been decided that a 1-wire rewrite-sense group will be used with the wire terminated at both ends and broken into sections of 2048 words. This requires that the rewrite drivers supply twice as much current as is normally required which, of itself, is no great disadvantage or additional expense.

The problem, which has been previously discussed in these progress reports, of interaction of the sense signals has been resolved. It is found experimentally that the inductive coupling of signals from one digit wire to another is quite negligible by reason of the restriction of the magnetic field by the ferrite, even in its saturated state. This leaves only the capacitive coupling between digit wires which, if the sense signal rise time is long compared to the propagation time down the wire, produces a so-called common mode effect (i.e., the potential of the whole wire moves due to cross-coupling). This effect can be rejected by a difference amplifier attached to the two ends of the wire. This is, then, another reason for breaking the rewrite-sense wire into four, 27-feet lengths.

The present X-Y drivers (vacuum tube) are very large (0.25 cu. ft.) which makes it highly desirable that they be transistorized. The enticing method of driving the words "directly", without using transformers or magnetic switches, requires the use of diodes in a quantity which would be very expensive, due primarily to the large power dissipation and, to a lesser degree, the reverse voltages required. The compromise which has been chosen for further investigation is that of driving the switch cores with transistors. This method is difficult for at least two reasons, the first being that the X and Y lines can no longer be terminated because of collector voltage limitations, the second being that the transistor collector must withstand twice the voltage drop across the primary winding of the switch because of the required backswing to produce write current. This investigation has not yet reached the point that any definite decisions regarding its economic and technical feasibility can be made.

(S. R. Ray)

Preliminary tests have been made on the two Transitron 2N546 transistors received, but no conclusive results have been attained yet. More time was spent checking calculations on the equivalent circuit of the wires in a core plane, and a conclusive check was attained by performing the calculations two different ways.

(J. L. Muerle)

4. Input-Output and Auxiliary Storage

Several output circuits for the tape-writing function are being analyzed using small-signal-circuit theory and dc-design techniques. The parameters of the 2N560 of Western Electric are being used. The aim is to get a better understanding of what characteristics the writing head should have. Work is continuing on thyristor scaling circuits.

(T. A. Murrell)

The design of a scaler to be used in pinch-roller counting was completed and some work was done on a relay-driving circuit to be used in conjunction with the scaler.

(T. C. Piper)

Peak detection of distorted readback signals from high-density magnetic recording is being studied. Two schemes of peak detection are being designed for non-return-to-zero recording. It is hoped that the detection circuit will be able to detect deteriorated readback signals with amplitudes down to 10% of the normal values.

(C. Liu)

A three-stage model of the ring counter mentioned in previous reports was tested successfully. Some modifications will be required in the input circuit for the full-sized version. The tape transport manufacturer has reported that delays encountered in fabrication of our machine will make delivery impossible before about May 15.

(R. L. Cummins)

PART II

MATHEMATICAL METHODS

Flows Behind Shocks (Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

A report on shock waves attached to a solid boundary has been written. In this report a general relation between the curvatures of the streak-lines behind the shock, before the shock and of the shock has been obtained. This relation contains the results of Thomas, Taub and Brown as special cases. Consequences of these relations are derived which extend the results of Tsien and Lin and Rubinow to pseudo-stationary flows. The case of a flow past a straight boundary with a normal shock and a uniform flow ahead of the shock is discussed in some detail. Under the assumption that the flow is regular near the point of attachment it has been proved that the derivations of odd order of the curvature of the shock are zero at the point of attachment. The case when the curvature of the shock at the point of attachment is allowed to become infinite is also discussed. For straight boundaries and uniform flow ahead of the shock approximations for the streak-lines and the shock near the point of attachment are obtained in this case.

(Y. S. Chow)

PART III

ILLIAC USE AND OPERATION

Illiac Program Library Routines

During the month of March, one new routine was added to the Illiac Program Library.

M24-260 Complete Linear Matrix Equation Solver and General Matrix Inversion Routine Using Drum Storage (DOI only). This is a complete routine which solves the matrix equation $Ax = B$ by methods similar to M13 and M14 but with increased capacity and more flexible input-output features. If A is an $n \times n$ matrix, and B is an $n \times m$ matrix, then the routine will accommodate

$$n + m \leq 164$$

$$n^2 + 2nm + 3n \leq 20,420 \quad .$$

In addition, the user has the option of taking the input to this routine either from the tape reader or from the drum. The user has the option of placing the output either on the drum or on the tape punch.

(S. J. Penny)

Statistical Library Routines

Two new routines were added to the Digital Computer Laboratory Statistical Library.

KSL 5.30-259 Matrix Transposition With or Without Rescaling (SADOI only). This routine will transpose an input matrix, or rescale such a matrix, or both.

(J. Hurley and K. Dickman)

KSL 5.50-261 Delete Rows and Columns From a Matrix (SADOI only). This routine will extract an arbitrary submatrix from a given larger input matrix.

(K. W. Dickman)

Illiac Usage

During March, specifications were presented for 18 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1339. Numbers followed by T are for theses.

1339 Bureau of Economic and Business Research. An Economic Model of Investment Allocation. The problem involves determination of the values of two variables, the stock of investment goods and the stock of consumption goods, over a period of time, given certain parameters which will be varied. The equation of the model is a difference equation, and thus involves finding the roots of a polynomial of the form

$$x^{n+1} - x^n(1 + \frac{w}{\beta}) + (\frac{w}{\beta}) = 0 \quad .$$

The roots of this equation will be used with the initial conditions specified in a system of equations to solve for the specific solution of the original difference equation. These roots are used as coefficients in the system of equations, and powers from 0 to n+1 must first be computed for them. As n will be 15 or 30, the Illiac will probably be used to compute the powers of the roots.

1340 Theoretical and Applied Mechanics. Launcher Dynamics Study. A tactical missile launcher must be light weight. As a consequence, the launcher is flexible. When a missile is launched from such a system, it has, at the end of guidance, an angular velocity which originates in the flexibility of the system. Bounds set on target dispersion limit the amount of initial angular velocity; that is, angular velocity at the end of guidance that can be imparted to the missile and still maintain the required accuracy. For a structure of given design, the main problem is to determine the initial angular velocity of the missile as a function of the geometrical and material parameters which characterize the structure. The problem has been cast into mathematical form by assuming the structure to be a combination of spring-connected masses subjected to the action of the missile moving along it. By application of LaGrange's equations, a system of seven ordinary differential equations is obtained. For the integration process, library routine F1 is used. In addition, eigenvalues for the homogeneous system are computed by using M19.

1341 Psychology. Personality Factors in Juvenile Delinquency. Four tests and one rating alleged to measure personality traits contributing to delinquent behavior have been administered to 400 subjects. Each of the tests and the scale will be factorized, and factor scores correlated with each other and with a number of other variables (history of recidivism, legal severity of delinquent act, etc.) to permit more adequate measurement and interpretation of personality traits evidently conducive to delinquent behavior. The following operations will be performed in accomplishing this aim:

1. Intercorrelations between variables in each test will be obtained (KSL 2.40 and 2.00).
2. Results will be printed in manageable form (KSL 5.57).
3. Centroid factors will be extracted (KSL 1.20).
4. Factors will be rotated in accordance with varimax criterion.
5. Factor scores will be obtained elsewhere (Statistical Service Unit), intercorrelated, and related to a number of non-test-variables (KSL 2.00).

1342 T Zoology. Locomotory Activity Rhythm of the Plains Garter Snake. An attempt is being made to determine to what extent various environmental factors, such as humidity, temperature, day length, etc., control or modify the locomotory activity rhythm of the plains garter snake. The method of least squares is being used to do this.

1343 Mathematics. Solution of a Differential Equation by Milne's Method. The differential equation $y' = y - \frac{2x}{y}$ with initial conditions $y(60) = 11$ is to be integrated by Milne's method from $x = 60$ to $x = 26$. The Illiac will be used to perform the integration. The problem has a number of interesting aspects, the most important being that although the analytic solution is a very smooth curve, the numberical solution becomes highly unstable and oscillates very widely near the end of the interval of integration.

1344 Physics. Cyclotron Phase Shifts. In a conventional cyclotron, particles at different points of the orbit get out of phase with each other unless the magnetic field strength is such as to compensate for the relativistic mass increase. It is

proposed to augment the base field, $H_B(r)$, with five auxiliary coils, $h_i(H_{B,0j}\ r)$, so that the total field

$$H_{ex}(r) = H_B(r) + \sum_{i=0}^{4} E_i\ h_i(H_{B,0j}\ r)$$

minimizes the phase shift at certain points of the orbit,

$$\phi_i = \sin^{-1} \frac{\pi}{V} \int_0^T \frac{\frac{T}{E_0} - \nu}{1+\nu}\, dT$$

where

$$\nu = \frac{H_{ex}(r) - H_{res}(0)}{H_{res}(B)} ,$$

and

$$T^2 + 2TE_0 = e^2\ r^2\ c^2\ H_{ex}^2\ (r) \quad .$$

Given $H_B(r)$, $h_i(H_{B,0j}\ r)$, it is desired to calculate E_i, $H_{res}(0)$ so as to minimize the largest ϕ_i .

1345 Bureau of Educational Research. Reliability of Stratified Test. There are various formulas proposed for determining the reliability of a stratified test; some are relatively simple, and some are complicated but mathematically more plausible. It is desired to find out how much difference in conclusion different formulas actually make. Number of items in the test and in each stratum (distribution), and distribution of item difficulty are to be taken into account. Steps to be taken by the Illiac are:

1. pick up items randomly within the range prescribed by the sampling plan; determine difficulty of each item;
2. produce item-by-item covariance matrices for several values of item tetracoric intercorrelation;
3. apply four formulas proposed for internal consistency reliability of stratified test; print results.

1346 Physics. Critical Current in Superconductors. Values of J' are to be computed by

$$J' = y + \frac{3}{2}\ \frac{r^2}{y} \ln(2r) - 3\left(\frac{r}{y}\right)^2 \int_0^1 du\left[\frac{uy - \frac{1}{2}}{1+e^{2\beta\epsilon_0(0,0)\left(\frac{r}{u} - y\right)}} - \frac{uy + \frac{1}{2}}{1+e^{2\beta\epsilon_0(0,0)\left(\frac{r}{u} + y\right)}}\right] \frac{\sqrt{1-u^2}}{u^4} \quad .$$

The values for $\beta = \frac{1}{kT}$ are fixed at one of ten temperatures. $\epsilon_0(0,0)$ is fixed. The parameters r and y are related through the subsidiary condition

$$-\ell n(2r) = \frac{r}{y} \int_0^1 du \left[\frac{1}{1+e^{2\beta\epsilon_0(0,0)(\frac{r}{u} - y)}} - \frac{1}{1+e^{2\beta\epsilon_0(0,0)(\frac{r}{u} + y)}}\right] \frac{\cosh^{-1}\frac{1}{u}}{u^2} .$$

Values of r are picked and a procedure (combined regula falsi and iteration) is used to determine the corresponding value of r to three significant figures. Values of J' for this pair of (r,y) are computed and stored (these will be a maximum in J' and this will be the critical current according to the theory). A modified Gaussian integration scheme is used. Preliminary calculations will be used to compute new weights for use in the a_i's of E5. This will automatically take the integrals weighted by $\frac{\sqrt{1-u^2}}{u^4}$ in J' and $\frac{\cosh^{-1}\frac{1}{u}}{u^2}$.

1347 Physics. Polarization of Bremsstrahlung Produced by Multiply-scattered Electrons. Calculation of the polarization of bremsstrahlung involves, for each angle of observation, integration over the angle of the scattered electron, as well as integration over the azimuthal angle. Multiple scattering of the electrons producing the bremsstrahlung complicates the integrand. Several such integrals will be done numberically using Simpson's rule integration. Parts of the integrand are obtained by interpolation of tabulated functions which will be input to Illiac.

1348 Astronomy. Discrete Source Field. It is required to find the potential distribution along a line due to an arrangement of about 1,000 radiating sources on a parallel line segment where the wave-length is small compared to the dimensions of the system. This will be found by straightforward summation, except that use is made of the almost-periodic character of the terms in cutting down the work required. Of particular importance is the local variation in phase. (This problem is connected with the new radio-telescope.)

1349 Chemistry. Solution of Equation for Chemical Rates. This is a continuation of Problem 1115 in three dimensions. The aim is to calculate the rate constants for the reactions

$$AB + CD \longrightarrow AC + BD .$$

More particularly for the reaction

$$H + H_2 \longrightarrow H_2 + H$$

(the orthopara conversion). The calculation involves the determining of the wave function and scattering cross sections for different kinetic energy for a passage of a particle through a potential barrier (calculated by means of London Eyring approach and the Hirschfelder approach semi-empirically from spectroscopic data). The scattering cross section will then be related with the chemical rate constant.

1350 Agricultural Economics. Factors in Rural and Urban Migration in Illinois. This research problem is concerned with a factor analysis of data taken from the reports of the Bureau of the Census which relate to rural and urban migration in 102 Illinois counties. The data are concerned with basic demographic and socio-economic variables descriptive of migration. The analysis proposed should derive factors which indicate the relative importance of variables assumed to be independent in migration theory. The steps to be taken in this analysis are:

1. computation of correlations of 57 variables
2. determination of communalities
   a. preliminary factors derived
   b. estimation of communalities
3. extraction of factors
4. rotation of factors orthogonally
5. rotation of factors obliquely .

1351 Physics. V_K-Centre. These sums are necessary in calculation of the polarization around a V_K-centre in an alkali halide crystal. This evaluation is necessary in the determination of the energy levels and wave-functions of the trapped hole on two negative ions, which is the present model of the V_K-centre. The energy levels and wave-functions, when available, will permit us to estimate the spectral and magnetic properties of the V_K-centre which have been observed experimentally by various people. It will enable conclusions to be drawn regarding the correctness of the model. In the evaluation of the polarization effect, the lattice is assumed to be made up of point charges in estimating the potential at each ion. The present summations arise in the estimation of this potential.

1352 Economics. Two-stage Least Squares. The problem is to estimate matrices of parameters β and γ in the matrix equation $\beta Y_v + \gamma Z_v = C_v + u$, where the system is over-identified, and where Y is a vector of variables endogenous to the system. Z is exogenous.

1. The equation becomes $Y_v = \beta^{-1} C - \beta^{-1} \gamma Z_v + \beta^{-1} u$.
2. Input Matrix $[Y,Z]$ where matrix is observed values at Y_i and Z_i over periods T.
3. Solve $\hat{Y} = Z(Z^T Z)^{-1} Z^T Y$ where $\hat{Y}$ are new estimates of Y using the reduced form of the system.
4. Punch $[Y, \hat{Y}, Z]$.

K14 will be used to find β_i's and γ_i's for each equation independently using $Y_1 = b_2\hat{Y}_2 + b_3\hat{Y}_3 + \dots + b_\epsilon\hat{Y}_\epsilon + \gamma_1 Z_1 + \gamma_2 Z_2 + \dots + \gamma_K Z_K$. This problem will involve writing a program to handle 1,2,3, and 4 above. The problem fits into an over-all research project involving parameter estimation in economic models.

1353 T Aeronautical Engineering. Impact of Shock Wave on Free Plate. The problem is to solve the first-order, ordinary differential equation $\frac{du}{dt} = f(u)$, where $f(u) = A[1 + CX(X + \sqrt{1+X^2})] - B[1 + CY(Y + \sqrt{1+Y^2})]$, and $X = a(b-u)$, $Y = cu$. u represents the velocity history of a plate after impact by an incident shock wave.

1354 Theoretical and Applied Mechanics. Stresses in Shells of Revolution. The problem is to determine the stresses in various solids of revolution subjected to internal pressure. The body is considered composed of rings; the forces between the rings are the unknowns that may be found from a set of Chapeyran equations. The Illiac is to be used in solving these 10-30 linear equations.

1355 T Physical Education for Men. Factor Analysis of Cardiovascular Variables. The research problem involves the determination of the main factors associated with cardiovascular fitness of normal males between the ages of 18 and 35. One hundred male subjects were given a total of 104 tests involving the heart and circulatory system under controlled conditions. From the previously reported data in the literature and also from personal observations, it appears that individuals may well score high on some tests and low on others or vice versa. The correlations between certain variables has been very low. However, to date, no attempt has been

made to factor analyze such data. At this time, the immediate problem concerns the obtaining of an inter-correlation matrix with the aid of Illiac techniques. After this is obtained it is hoped that the Illiac may aid in the determination of the various factors associated with this study.

1356 Psychology. DuBois-Loevinger Homogeneity Method. The problem is a fairly common one in psychological research and development, the grouping of items into clusters which are to be as homogeneous as possible, which are mutually exclusive, and which are reasonably independent. For large numbers of items (100), a repeated application of a simple ratio of a sum of covariances to a sum of variances as a test criterion is the heart of the program. One item is assigned to one of an *a priori* collection of items at each iteration print-out of development, and the final matrix of the test ratio for each item and cluster is required.

Table I shows the distribution of machine time for the month of March.

TABLE I

	Hrs:Mins		
Regular Maintenance	30:32		
Unscheduled Maintenance	11:55		
Drum Engineering	30:01		
Leapfrog	33:57		
R.A.R.	3:36		
Library Development	2:21		
Wasted	:00		
		112:22	
Use by Departments			
Computer	32:44		
Physics	28:52		
Control Systems Laboratory	56:31		
Structural Research	80:17		
Struct. Res. (AF 464)	31:25		
Struct. Res. (A.A.S.H.O. Road Test)	3:29		
Aviation Psychology (AF 49(638)371)	7:35		
Psychology	34:40		
Sociology	3:36		
Inst. of Com. Res.	2:29		
Inst. of Com. Res. (9067C)	4:15		
Education	3:24		
Bureau of Educational Research	5:10		
Economics	1:54		
Economics (NSFG 7056)	5:00		
Theor. and Applied Mechanics (ORD 593 IC)	25:34		
Mechanical Engineering (ORD 1980)	:29		
Electrical Engineering	10:33		
Elect. Eng. (AF 6079)	:28		
Elect. Eng. (NOBSR 64723)	:38		
Elect. Eng. (NSFG 7421)	:20		
Met. and Min. Engineering (AF 3789)	:09		
Chemistry	51:09		
Agriculture	23:16		
Astronomy (NONR 1834(22))	1:01		
College of Medicine	3:55		
State Water Survey	2:44		
State Water Survey (46-26-84-312)	1:36		
State Department of Public Welfare (1715)	:51		
Michael Reese Hospital, Chicago	1:16		
Eastern Ill. U. (Botany)	:40		
U. of North Carolina (Psychometric Laboratory)	1:36		
Classes	14:17		
Demonstrations	5:00		
Miscellaneous	27:11		
		474:04	
			586:26

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance, and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for March.

TABLE III

Reader	4
Punch	2
Input	3
Output	1
Drum	13
Arithmetic	1
Memory	1
Other	5
Unknown	1
	31

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUPTIONS OR FAILURES STOPPING OK TIME	SCHEDULED ENGINEERING	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/2/59	21:35	:06	1	2:19	(1) Reader "G" error	:00	:40	0
3/3/59	20:35	2:26	2	:59	(1) Drum Error (2) Reader "B" error	:00	1:35	0
3/4/59	16:37	4:40	2	2:43	(1) Arithmetic error (2) Drum error	:00	:47	1
3/5/59	20:38	:24	2	2:58	(1) Reader "G" error (2) Fuse blew in Illiac	:00	:39	0
3/6/59	18:54	3:19	3	1:47	(1) DC fuse blew (2) Output error (3) Unknown	:00	1:22	0
3/9/59	22:45	:21	2	:54	(1) Runover from engineering time (2) Possible input error	:00	1:11	0
3/10/59	20:39	:39	1	2:42	(1) DC fuse blew	:00	:33	0
3/11/59	21:24	:23	2	2:13	(1) Drum error (2) Punch #4 error	:00	1:14	0
3/12/59	21:26	1:01	3	1:33	(1) DC fuse blew (2) Drum error (3) Drum error	:00	1:28	0
3/13/59	22:33	:29	2	:58	(1) Drum error (2) Drum error	:00	:40	0
3/16/59	21:04	:05	1	2:51	(1) Reader "G" error	:00	:58	0
3/17/59	21:22	:00	0	2:38		:00	1:02	0
3/18/59	21:26	:00	0	2:34		:00	:39	0
3/19/59	21:45	:15	2	2:00	(1) Drum error (2) Drum error	:00	:57	0
3/20/59	21:43	:50	1	1:27	(1) Memory error 2^{-33}	:00	:45	0
3/23/59	20:55	:00	0	3:05		:00	:44	0

DATE	RUNNING OK TIME	REPAIR TIME	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	SCHEDULED ENGINEERING	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
3/24/59	23:00	:00	0	1:00		:00	:42	0
3/25/59	20:16	2:10	1	1:34	(1) Drum error	:00	1:03	0
3/26/59	21:48	:16	1	1:56	(1) Punch #3 error	:00	:57	1
3/27/59	21:35	:25	2	2:00	(1) Input error (2) Input error	:00	:45	0
3/30/59	21:33	:08	1	2:19	(1) Drum error	:00	:30	0
3/31/59	21:03	:37	2	2:20	(1) Drum error (2) Drum error	:00	:51	0
TOTALS	464:36	18:34	31	44:50		:00	20:02	2

PART IV

IBM 650 USE AND OPERATION

Since the air conditioning equipment for the IBM 650 installation has not yet been installed, the computer was turned off and was unavailable for use during the month of March in order to prevent any possible damage to the equipment. The machine was operated for brief periods of the order of one hour once or twice per week in order that the staff of this laboratory could continue library program development.

IBM 650 Library Routines

During the month, seven routines were added to the 650 Library.

P2'-13' Punch 1-8 Words Per Card. This routine punches from 1 to 8 words per card, the number of cards punched being the next integer greater than or equal to the number of words punched divided by the number of words per card. Punching may be either from the drum or from high-speed storage.
(K. K. Shannon)

S3'-14' Fixed-Point Logarithm. This routine computes the natural logarithm of an argument using the fixed-point mode of operation of the machine.
(K. K. Shannon)

T3'-15' Fixed-Point Sine and Cosine. This routine will compute either the sine or the cosine of an argument using the fixed-point mode of operation of the machine.
(M. T. Gray)

D1'-16' Regional Trace Routine. This routine is used in order to aid in checking other programs. For each order executed between specifiable limits in the tested routine, a card is punched. This card gives the location of the instruction, the instruction, the contents of the upper accumulator, the lower accumulator, the distributor and the three index registers.
(M. T. Gray)

S4'-17' Fixed-Point Exponential. This routine computes the exponential of an argument using the fixed-point mode of operation of the machine.

(K. K. Shannon)

P3'-18' Card Punch Subroutine. This routine will punch 1 to 7 words per card in a format consistent with the X1'-1' input routine.

(R. H. Flenner)

P4'-19' Card Punch Subroutine With Zero Deletion. This routine which punches 7 words per card will omit any block of 7 words which is identically zero. It can also serve as a dumping routine for diagnostic procedures and for dumping one-word-per-card programs onto 7-word-per-card format for subsequent read-in. The card format is consistent with the X1'-1' input routine.

(R. H. Flenner)

IBM 650 Usage

During the month of March, one new problem specification was submitted.

8' Agricultural Economics. Optimal Farm Programming. The problem involves application of linear programming techniques to intra-farm resource allocation.

PART V

GENERAL LABORATORY INFORMATION

Reports and Seminars

Report

Report No. 85, "The Use of Chebyshev Matrix Polynomials in the Iterative Solution of Linear Equations Compared to the Method of Successive Over-relaxation", by G. H. Golub, March, 1959.

Seminars

"Programming for Illiac II - The Input Routine", by Mr. Charles W. Gear, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, March 2, 1959.

"A New Program for Circuit Tolerance Analysis", by Dr. Lloyd D. Fosdick, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, March 9, 1959.

"Developments Leading up to the Rapid Reader for Bubble Chamber Data Processing", by Dr. Bruce McCormick, Radiation Laboratory, University of California, Berkeley, California, March 16, 1959.

"Models of Transistors for Switching Applications", by Dr. John G. Linvill, Stanford Electronics Laboratories, Stanford University, Palo Alto, California, March 23, 1959.

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UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - SWITCHING CIRCUIT THEORY

PART III - ILLIAC USE AND OPERATION

PART IV - IBM 650 USE AND OPERATION

PART V - GENERAL LABORATORY INFORMATION

April, 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The Rich Electronic Computer Center at Georgia Institute of Technology is participating in this work by the support of a staff member at the University of Illinois.

1. Basic Circuits

All types of restoring circuits were modified to accomodate output selectors (see March 1959 report). Two kinds of selectors and their associated drivers were designed:

a. Selectors with a completely restored output and a fan-out of 5. This system uses large swing drivers (+ 2.9v, − 3.1v) and n + 1 transistors for an n-way selector.

b. Selectors with outputs of about ± 1.5v and a fan-out of 3. This system uses standard ± 2.5v swings. Only n transistors are used for an n-way selector.

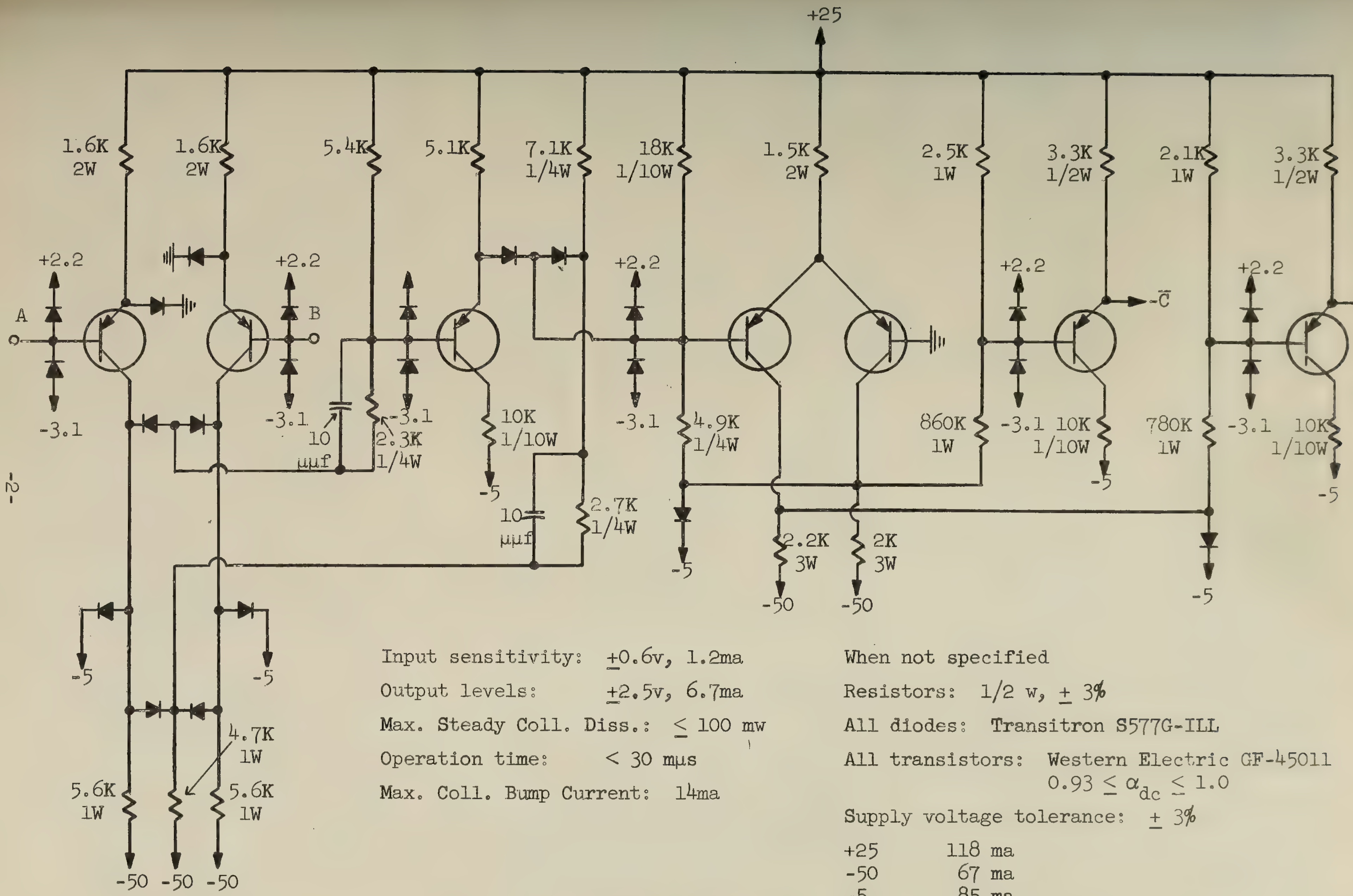
(N. E. Wiseman)

The drivers for the reduced swing requirements of F-elements were finally tested. It turns out that reducing their output swing to ± 1.0v has saved about 25% of the delay, rise and fall times: for this new design the delay time is less than 20 mμs and rise and fall times are less than 15 mμs.

(M. N. Schleifer)

A C-element racing register was built using the new type of element based on the use of ANDs and ORs at the collector level to set a Schmitt trigger. The operation time was found to be less than 30 mμs. This is shown in Figure 1.

(N. H. Johnson)



Input sensitivity: ± 0.6v, 1.2ma

Output levels: ± 2.5v, 6.7ma

Max. Steady Coll. Diss.: $\leq$ 100 mw

Operation time: < 30 mμs

Max. Coll. Bump Current: 14ma

When not specified

Resistors: 1/2 w, $\pm$ 3%

All diodes: Transitron S577G-ILL

All transistors: Western Electric GF-45011
$0.93 \leq \alpha_{dc} \leq 1.0$

Supply voltage tolerance: $\pm$ 3%

+25	118 ma
-50	67 ma
-5	85 ma
+2.2	-11 ma
-3.1	-15 ma

Figure 1

Collector Logic C-Element

The drivers for the flow-gating system were completed and tested. With 2N560 output stages rise and fall times of 20 mμs were observed with an output current of 185 ma at -35v into a resistive load. Although not mandatory, heat-sinks were attached to the emitter-follower 2N560 transistors. Figure 2 shows the circuit used.

(H. Guckel)

Further work was done on the direct measurement of intrinsic time constants (see March 1959 report). It turned out that the sensitivity of the zero-charge indicator was insufficient. Several bridge circuits are being investigated.

(W. J. Poppelbaum and G. E. Buenger)

2. Shifting Register Test Unit

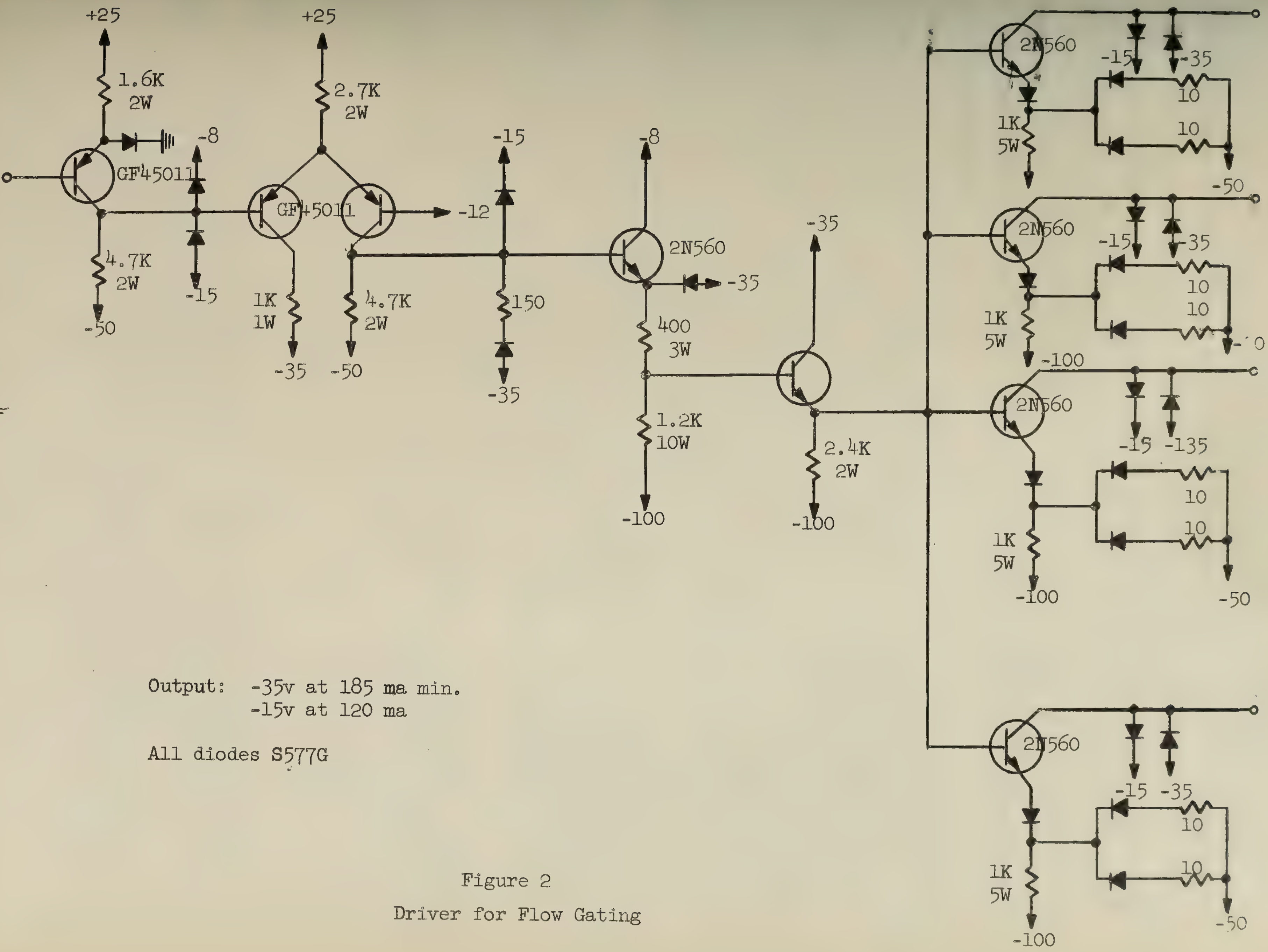
After a false start hampered by two stoppages, one due to the pilot lamp serving as fuse in the control box having burnt out, the other probably due to the fan not cooling the unit properly, an attempt was made to break the previous error-free running time records.

Unfortunately this attempt was foiled by human intervention in two instances: it was found empirically that turning the fan on or off while the scope synch lead happens to be connected to the unit causes the auxiliary counter to go to an illegal state. The second intervention was caused by a campus-wide power interruption. Discounting these two stoppages the unit had been running without errors of its own for 686.9 hours at 0800 on May 1, 1959. It had run for 386.6 hours before the first stoppage, 67.1 hours till the second stoppage, and had been running for 233.2 hours at 0800 on May 1, 1959.

(G. A. Metze)

3. Core Storage Unit

A large portion of the memory development effort during the month was spent on development of transistorized X-Y driving methods. The most difficult problem thus far has been that of causing the current in the X and Y drive lines to come up to full value in about 100 mμs within the existing economical constraints. The advantages of a fast-rising X and Y current were not originally considered to be as important as they now appear to be. This importance seems to stem from the fact that the more slowly rising H field spreads the read current out in time, reducing its peak value and thereby increasing the switching time of the bit cores and the peak output amplitude.



Output: -35v at 185 ma min.
-15v at 120 ma

All diodes S577G

Figure 2
Driver for Flow Gating

The load-sharing method was investigated to some extent to try to reduce the initial energy which must go into the primaries of the half-selected switches and thus lower the peak voltage drop required across an X or Y line. It was found however that for transistors now available, the load-sharing method is too uneconomical. The method presently being pursued is simply to split the switches into 1024 word groups (32 x 32) which with the reduction of primary turns from 4 to 2 results in an effective primary inductance of 0.14 μh per switch core. This arrangement allows the current to rise to 700 ma with only about 32v drop across the line and a resulting read current of about 1 ampere. This arrangement requires 256 drivers per 4096 word memory.

The further reduction of primary turns from 2 to 1 is also being considered. If this method were used, it may be possible to utilize a driver transistor with lower collector voltage and higher current rating since the primary inductance should be lower for the case of 1 primary turn. It appears, however, that transistors supplying more than 1 ampere and capable of switching in about 100 mμs are not yet available. Nevertheless, a driver in the 1.25 to 1.5 ampere and 200 mμs range might be adequate. Thus, the design of a 1.25 ampere driver with a rise time on the order of 200 mμs was attempted. The main driver transistor used was a Transitron ST401. This was driven by first a GF45011 followed by a 2N560.

It was found that a 200 mμs rise time seems feasible, but that it must be paid for in the use of several nonstandard voltages and another transistor besides the GF45011 and 2N560. Further, if some type of current regulation is desired such as with a constant current emitter, there will be at least one resistor in the driver with a power rating of 100 watts or more.

A driver is being designed now with a 1.5 ampere, 30 volt output. Transitron ST400 transistors will be used in this driver. Some of the experience of this month will be put to use in this driver. It is hoped that a 200 mμs rise time can be attained.

(J. L. Muerle and S. R. Ray)

Memory Timer

In March the memory timer design was completed and a prototype was built using a fixed 600 mμs delay line as the delay element. Some modifications to the circuit were found to be necessary on the basis of this experience.

In April it was decided to make the timer easily adjustable by using a variable delay line. This required that a high current gain emitter-follower be

designed to pick the signal off the adjustable tap on the delay line. The emitter-follower design was tolerance analyzed by code 1206. A commercially produced 0-500 mμs delay line arrived, and the prototype timer was modified using it. At present a 50 → 500 mμs pulse length timer is operating with a rise time of approximately 20 mμs. No tests have been conducted as yet on the stability of the pulse length.

(J. D. Leslie)

The idea of using a Schmitt trigger flipflop to reshape the incoming sense signal was abandoned since it would require two such flipflops because of the ternary logic needed for error detection. It was then decided that the incoming signal would be of a long enough duration to allow direct coupling from the collectors of a difference amplifier into emitter-followers which would in turn feed two F-elements for storage and error detection. Because of the expense of two F-elements per digital position, it was proposed to use a register of six flipflops and, with diode logic, have the register indicate the address of the sense wire that was in error. This would mean that each amplifier would have to be capable of driving a maximum of five flipflops. However, if ten flipflops were used in the register, then by proper coding the drive requirement could be reduced to a maximum of two flipflops per amplifier. The coded error approach has the disadvantage that the storage in the 53 flipflop output register is not checked, since the error is sensed prior to storage. A 3 state flipflop at a cost of 6 transistors has been suggested, as compared to a 2 state flipflop at a cost of 4 transistors. The possibility of using this 3 state flipflop is presently being looked into. In addition the amplifier stage of the sense amplifier and error detection circuit is being studied for a possible minimum signal to noise ratio of three which looks promising.

(A. B. Lindquist)

4. Auxiliary Storage

A writing circuit for use with the Ampex tape unit head has been designed, using three 2N560 transistors as a phase inverter followed by a pseudo push-pull pair, one operating as a common emitter and the other as a common collector. The design shows some features that must be held to critical values in order to equalize the two gain paths, and should be regarded as a stopgap until symmetrical n-p-n, p-n-p pairs with characteristics comparable to the 2N560 are available.

(T. A. Murrell)

Tolerance analysis of the ring counter stage has been completed. Modifications of the clock pulse generator are being made.

Further delays in the tape transport delivery have been reported by the manufacturer; delivery is not expected before May 30th.

(R. L. Cummins)

Use of thyristors in scaling circuits was investigated. No reliable new design using thyristor properties was found. Work is now being directed toward completion of circuitry necessary to monitor the number of pinch roller operations, the total running time for each mode of operation, etc., on the Ampex tape transport.

(T. C. Piper)

The investigation of peak detection of magnetically recorded digital signals without differentiation of the read back signals continued during the month. A circuit is being designed to test two different schemes for detecting the signal peaks.

(C. N. Liu)

5. Arithmetic Unit

Using the standard circuits of File No's 267 and 272, plus the circuit rules for diode logic of File No's 273 and 276, several of the basic elements of the arithmetic unit were designed. In particular, the data paths for three proposed arrangements of the arithmetic unit were implemented:

a) Plan H as described in Report 80.

b) A modified Plan H, differing by:

1. the absence of the bilateral X1 path interconnecting the $\bar{A}$ and A registers:

2. an added X4 path on the output of the pseudo-adder into $\bar{A}$.

The first change was prompted by the latest circuit delay specifications, which make the difference in delay between a direct path from register to register versus the pseudo-adder path negligible. The second change results from the fact that by providing two options for gating the pseudo-adder into $\bar{A}$ and two options for gating $\bar{A}$ to A, the four combinations can cover the one digit* right, one digit* left, and zero shifts, in addition to providing a 2 digit* right shift. The last option allows reduction of multiply time.

*Each digit is a base four digit.

c) Plan U, shown in figure 3. Adders in both the A to $\bar{A}$ and $\bar{A}$ to A paths are made economically feasible by use of diode logic and are employed to further accelerate the multiply operation.

A more detailed study of the controls necessary and the speeds obtainable for design U is being conducted. The final results will be expressed in terms of performance specifications of power drivers now being developed.

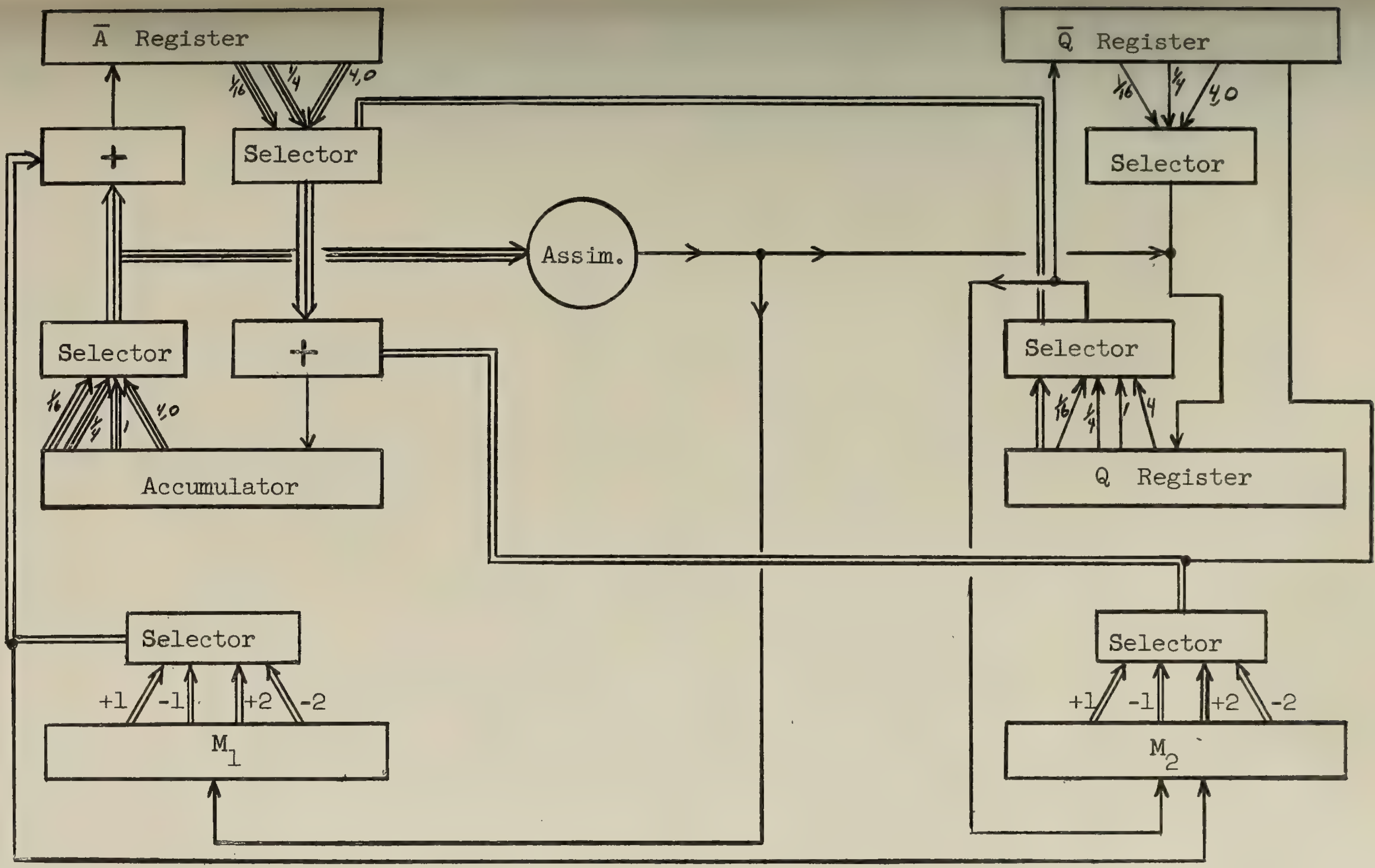
(R. R. Shively)

6. Diode and Transistor Procurement

Approximately 2800 Western Electric type GF45011 transistors were received in 1959 prior to May 1st, for a total of 4000 units received against the present order for 5000. In addition, 50 units meeting the same specifications were received from Texas Instruments. As of May 1st, bids were requested for an additional order of 6000 units, with bids to be opened about May 14th.

A quantity of 500 type S577G diodes was received in late March and during April. After soliciting and opening bids, an order for 15,000 units was prepared, and now awaits approval.

(J. E. Robertson)



Single Wire Connections
True and Complement Connections
True and Complement Where a Stored Carry is also Associated with each Digit

Figure 3

Design U

PART II

SWITCHING CIRCUIT THEORY

(Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

1. Semi-Modular Circuit Theory

The doctoral thesis of Mr. James H. Shelly was completed. The following is an abstract of his thesis.

This paper is based on a theoretical investigation of two problems in the theory of semi-modular switching circuits. These problems are those of deciding whether there is some semi-modular circuit corresponding to a given specification, and of constructing such a circuit. The problem specification is assumed to be a set L of n-dimensional vectors whose components are non-negative integers, such that the corresponding circuit has L as its C-state lattice. (The C-state lattice is the set of component-wise lengths of sequences of states x(i) of a semi-modular circuit. These sequences have the property that for x(i) in the sequence, x(i+1) is a possible choice for the next state of the circuit.)

Two equivalence relations are defined for general sets of n-dimensional vectors whose components are arbitrary integers. The relation $\underline{a}\,\mathcal{S}\,\underline{b}$ is defined by $L(\underline{a}) = L(\underline{b})$, where $L(\underline{a}) = \{\underline{d} \mid \underline{d} + \underline{a} \in L \text{ and } \underline{d} \geq 0\}$. Let L be closed under the operation of taking the component-wise numerical maximum of any pair of elements of L, and let the number of equivalence classes of L under $\mathcal{S}$ (called $\mathcal{S}$-classes) be finite. Then any $\mathcal{S}$-class $\underline{A}$ determines a finite set $Q(\underline{A})$ of n-dimensional vectors whose components are non-negative integers. Any two elements $\underline{a}$ and $\underline{b}$ of some $\mathcal{S}$-class $\underline{A}$ such that $\underline{a} \leq \underline{b}$ may be related by an expression of the form $\underline{a} + \sum_i c_i\, q(i,A)$, where the summation index i ranges over the finite index set for the elements $q(i,\underline{A})$, of $Q(\underline{A})$. The coefficients c_i are non-negative integers. The jth component index is said to be spanned in $\underline{A}$ if for some $q(i,\underline{A})$ in $Q(\underline{A})$, $q_j(i,\underline{A}) \neq 0$.

Two elements $\underline{a}$ and $\underline{b}$ of L are defined to be in the same periodic class if the $\mathcal{S}$- classes which contain $\underline{a}$ and $\underline{b}$ have identical sets of indices which are not spanned, and $\underline{a}_j = \underline{b}_j$ whenever j is in the common set of unspanned indices. If $\underline{B}$ is a periodic class of L, then all $\mathcal{S}$-classes whose elements

appear in $\underline{B}$ have identical Q's. This implies that the basis Q may be interpreted as a function of the periodic class as well as of the $\mathcal{J}$-class. It is shown that for each periodic class $\underline{B}$ of L, and for each $q(i,\underline{B})$ in $Q(\underline{B})$, then there exists a constant $\lambda(q(i,\underline{B}),\underline{B})$ dependent only upon $\underline{B}$ and $q(i,\underline{B})$, such that if $\underline{a}$ and $\underline{b}$ are in $\underline{B}$ and $|\underline{a}_h - \underline{b}_h| < q_h(i,\underline{B})$ for some h, then $|\underline{a}_j - \underline{b}_j| \leq \lambda(q(i,\underline{B}),\underline{B})\ q_j\ (i,\underline{B})$ for all j such that $q_j(i,\underline{B}) \neq 0$.

The principal result of the investigation is to show that the class of all C-state lattices of semi-modular circuits corresponds to the class of all sets L which have a finite number of $\mathcal{J}$-classes and have property I. Property I means that the vector whose components are all 0 is the least element of L, L is closed under the operation of taking component-wise numerical maxima, and that covering in L means a difference of 1 in some one component. This result solves the decision problem.

Although the proof of the decision problem yields a synthesis method, another theorem presents conditions necessary and sufficient that a given synthesis be valid.

Finally, the restriction that the problem specification be a lattice is weakened to permit the use of the set of join-irreducible elements instead. As an application of the theory, the class of semi-modular circuits which have delays in all lines is characterized.

(J. H. Shelly)

2. Algebraic Methods

A paper entitled "Treatment of Transition Signals in Electronic Switching Signals by Algebraic Methods" was written and accepted for publication in the IRE Transactions on Electronic Computers. This paper is concerned with an algebraic system which is slightly weaker than Boolean algebra and which may be used for treating not only the limiting signals of electronic switching circuits, but also intermediate signals. The assumption is made that AND and OR elements produce minimum and maximum functions respectively for these intermediate signals. It is necessary to replace the two conditions:

for any a

$$(1)\ a\,\bar{a} = 0 \text{ and } a \vee \bar{a} = 1$$

which hold in Boolean algebra with the weaker condition:

for any a and b

$$(2)\ a\,\bar{a} \subseteq b \vee \bar{b}$$

This algebra turns out to be formally equivalent to the three-valued logic of S. C. Kleene, Introduction to Metamathematics, page 334. By use of this algebra, one may design circuits having equivalent behavior for such transition signals and consequently equivalent behavior during transition.

3. Logical Programming

The theoretical investigation of the nature of logic programs was made from the standpoint of computability. Let us imagine a computer, C, containing a program, x, and being fed with an input y. It has been shown that x and y may be represented as numbers. The computer under these circumstances, may either stop after producing an output, or else it may go into an endless cycle. We shall assume that an output occurs only in case the computer comes to a stop. A program, u, is defined as a logic program if it produces output 1 for input x only if the computer, when it contains program x, will produce output 1 for all inputs. The existence of such logic programs may be proved trivially. Logic programs may be partly ordered according to their ability to analyze other programs of the form x. A logic program u is said to subsume another logic program u* if u produces an output 1 whenever u* produces an output 1. An attempt was made to show that no maximum logic program exists which subsumes all other logic programs. The method used in this attempt was that of the diagonal proof of Goedel in his incompleteness theorem. This approach was unsuccessful, however, due to the implied separation of program from input in the description of the machine. Although it is quite conceivable that logic programs may be written for actual computers, it seems unlikely that programs could be written in such a way that they would provide a practical tool because the number of operations required for the logic program to perform its analysis would be prohibitively large and therefore it would be too slow.

It is possible, however, to modify the definition of a logic program in such a way that one might write a practical logic program. A modified logic program is defined as follows. The program u is a modified logic program if it produces output 1 for input $\Upsilon(v,x)$ only if program x has output 1 for all inputs. Here the function $\Upsilon(v,x)$ may be taken as any integral valued function from which it is possible to uniquely determine v and x. The quantity v entering

into the function is arbitary and is called the proof. In practice one would attempt to select v in such a way the program u would produce output 1 for the particular x under consideration. It may be shown that for any modified logic program u it is possible to construct a logic program of the original type which will produce an output 1 for input x, whenever there exists a v such that the modified program will produce an output 1 for input $\tau(v,x)$. In this case the unmodified program would have to carry out a searching procedure which would make it take a much longer time to carry out the calculation than the modified program would take. Similarly, the unmodified program may be seen to be a special case of the modified program. This equivalence between modified and unmodified programs enables one to study the situation theoretically using unmodified programs while restricting oneself to the writing of the modified type of program.

Another area of interest is the construction of methods of showing that two programs, both ostensibly logic programs, are, in fact, inconsistent with each other so that one or the other or both must not be a logic program. It is possible to write two programs which are inconsistent but such that neither may be shown not to be a logic program. An example of this situation is obtained in the case of the following statement: "Program x causes the computer to cycle indefinitely for some input." It is possible to write a program with the help of a given program u, ostensibly a logic program, which will affirm this statement. It is also possible to write a second program with the help of another program u*, also ostensibly a logic program, which will deny this statement, yet, it is not possible to write a program which will determine which of u or u* fails to be a logic program.

PART III

ILLIAC USE AND OPERATION

Illiac Program Library Routines

During the month of April four new routines were added to the Illiac Program Library.

M25-262 Eigenvalues and Eigenvectors of a Symmetric Matrix (SADOI only). This open subroutine uses the Jacobi method to find the eigenvalues and eigenvectors of a symmetric matrix. It is a complete revision of routine MO originally prepared in 1954 by R. T. Gregory. The revision applies more precise arithmetical procedures to the process and makes the mechanics of using the routine more convenient. Routine MO is now to be regarded as obsolete.

(W. A. Rosenkrantz)

K16-263 Modified Multiple Regression Analysis (DOI only). This routine is a revision of routine K14 and provides for drum storage of the input information so that it need be read only once in carrying out the various facilities provided by the routine.

(V. West and K. Dickman)

M26-264 Eigenvalues and Eigenvectors of a Symmetric Matrix - Complete Program (SADOI only). This routine is the complete program version of M25 above. It provides the input and output routines and a master control routine so that only the data for the matrix to be handled need be provided.

(W. A. Rosenkrantz)

AUX P20-265 Dataplotter Output Converter (SADOI only). This program is intended to convert a data tape which has been output from Illiac into a tape which can be used as input to the dataplotter.

(C. M. Sprankel)

Illiac Usage

During April, specifications were presented for 48 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1357 T. Numbers followed by T are for theses.

1357 T Civil Engineering. Response of Multi-Degree-of-Freedom Systems to Base Disturbance. A study of the effect of ground motion on various shear-beam-type structures is to be made. The response of each structure will be computed for the same ground motion and a study will be made of the various building parameters affecting the response with special emphasis on ground-building coupling. Varied accelerograms will be integrated by Newmark's β method to obtain displacements and shears. Scope plots will be made of the variation in these as a function of time.

1358 Computer. Heisenberg Ferromagnet. In this model a magnet is considered to be made up of an array of spins, s_i, on the sites of a lattice, each spin being represented by a vector of fixed magnitude, interacting with only its nearest neighbors according to the formula $E = -Js_i \cdot s_j$, and also interacting with the external field. The total spin, and its component in the direction of the external field, are quantized. The program is to estimate the magnetization and internal energy of such a model, as a function of the field and of the coupling, J. A Monte Carlo method is used, as follows:

1. The sites are taken one at a time, and an attempt is made to replace each spin by a random vector. The change in energy ΔE that would result is computed; if $\Delta E \leq 0$, the replacement is always made; if $\Delta E > 0$, the replacement is only made with probability $\exp(-\frac{\Delta E}{kT})$.

2. Several attempts are next made to replace the last spin by one which quantizes the total spin. The same rules as above are followed.

3. Several attempts are made to rotate the external field (equivalent to rotating every spin in the magnet) in such a manner that the component of total spin in its direction is quantized. Again, the same rules are followed.

4. If stages 2, 3 were successful, the quantum numbers and the energy are recorded; if not, we are not in a quantum state, and the results of the iteration are rejected.

These four stages form one iteration. An auxiliary program will compute the means and variances of the results of many iterations.

As written, the program operates on a simple cubic lattice of 2^3, 4^3, or 8^3 sites, with periodic boundary conditions. It will be possible to treat either the ferromagnetic or the antiferromagnetic case by choosing the sign of J. It is proposed to compare the results with those obtained by using the Ising model, by other theoretical methods and by experiment.

1359 Control Systems Laboratory. Analysis of Wind Waves. 3500 words of data are to be processed by a least squares technique to yield the best values of eight parameters and estimates of the probable error of each parameter. Residuals will be examined for trends. This problem represents a generalization of Problem No. 1228 and will use a faster program. Each term in the sum of squares contains a different integral of the paramaterized function.

1360 Agronomy. Studies in Polyploidy of Corn. The objective of this program is to study the influence of polyploidy on the performance characteristics of field corn. Illiac is used for analysis of variance in experimental data.

1361 Agronomy. Breeding New Varieties of Spring Oats. The purpose of this study is to develop and test new varieties of spring oats, having superior characteristics. Illiac is used for analysis of variance in experimental data.

1362 Agronomy. Breeding New Varieties of Winter Oats. The purpose of this study is to develop and test new varieties of winter oats having superior characteristics. Illiac is used for analysis of the experimental data.

1363 Agronomy. Performance Tests of Small Grain Varieties. The purpose of this study is to determine the adaptability of varieties of small grain to Illinois conditions. Illiac is used for analysis of the experimental data using analysis of variance routines.

1364 Agronomy. Forage Crop Management Studies. The purpose of this study is to determine influence of management practices on different varieties and species of forage crops. Illiac is used for analysis of experimental data using analysis of variance routines.

1365 Agronomy. Forage Crop Variety Trials. Analysis of variance routines are to be used with the objective of the study being to determine the adaptability of forage crop varieties to Illinois conditions. Illiac is used for analysis of experimental data.

1366 Agronomy. Sorghum Variety Testing. Analysis of variance routines are to be used. The objective of this study is to determine the adaptability of sorghum varieties to Illinois. Illiac is used for analysis of experimental data.

1367 Agronomy. Breeding New Varieties of Forage Legumes. Analysis of variance routines are to be used in connection with a study whose objective is to develop and test new varieties of forage legumes having superior characteristics. Illiac will be used for analysis of the experimental data.

1368 Agronomy. Establishment of Pastures. The object of this study is to develop more efficient methods of establishing pastures in Illinois. Illiac is to be used for the analysis of data.

1369 Agronomy. Development and Testing of New Corn Hybrids. The object of this program is to develop and test new corn hybrids for Illinois. Illiac is used for analysis of the experimental data.

1370 Agronomy. Nutrition Studies in Greenhouse Roses. The object of this study is to determine the influence of various nutritional factors in the yield and quality of greenhouse roses. Illiac is used to analyze the experimental data.

1371 Agronomy. Studies in Soil Management for Illinois. Analysis of variance routines are to be used to study the effect of various soil management practices on productivity of Illinois soils. Illiac is used to analyze the experimental data.

1372 Agronomy. Performance tests of Commercial Corn Hybrids. Analysis of variance routines will be used in a study to test commercially available corn hybrids for adaptability to all parts of Illinois. Illiac is used to analyze the experimental data.

1373 Agronomy. Studies of Strawberry Irrigation. Analysis of variance routines are used in connection with a study to develop adequate irrigation procedures for strawberry production in Illinois. Illiac is used to analyze the experimental data.

1374 Agronomy. Development and Testing of New Winter Wheat Varieties. The object of this study is to develop and test new varieties of winter wheat for Illinois. Illiac will be used for the analysis of the experimental data.

1375 Agricultural Engineering. Pneumatic Conveyor Characteristics. This is a study of pneumatic conveyors for feedstuffs for animals (soybean meal, corn, etc.). Illiac will be used to make a least-squares analysis of the data.

1376 Civil Engineering. Computation of the Maximum Response of a Single Degree of Freedom System. This program integrates the differential equation

$$\ddot{Y} = \alpha[F(D) - R(Y)] - \gamma\dot{Y} \quad .$$

The integration is carried to time D_t; $R(Y)$ is a multi-valued function of Y; $F(D)$ is a multi-valued function of the acceleration of the base of the system.

1377 Bureau of Educational Research. Illinois High School Testing Program. New psychological tests of special aptitudes (numerical and spatial) are being tried out for possible inclusion in the Illinois Statewide High School Testing Program in which 65,000 to 70,000 students are tested each year in some 550 secondary schools. In order to make decisions concerning which tests to include (of new tests) and which tests to delete, it is necessary to have data on variance and covariance. Approximately 5,000 cases have been sampled in order to stabilize the data over students and schools. Illiac will be used to compute correlation coefficients using standard Illiac routines.

1378 T Agricultural Economics. Optimum Calving Dates for Dairy Herds. The research problem is to determine the optimum months of the year to freshen dairy herds in order to maximize net returns to the farm. The linear programming technique (M15-183) is useful in solving this problem in that it allows a preference function to be maximized subject to given restrictive conditions. In this problem the preference function is an income equation and the restrictive conditions are the limited resources of the farm.

1379 T Chemistry. Variational Methods in the Calculation of Collision Cross Section. The problem of calculating the collision cross section produces various multi-dimensional integrals which must be evaluated. The integrals involved are nine dimensional and are to be evaluated by Monte Carlo techniques. One of these integrals is shown below:

$$T = \iiint_{\text{all}}^{\text{space}} \left[\frac{(1+c_3 e^{-r_3 \cos \Theta_3}) \sin (k_3\, r_3 \cos \Theta_3)}{r_3 \cos \Theta_3}\, \psi_3^* (1,2)\, \psi_0(2,3) \cdot \frac{\sin (k_0\, r_1 \cos \Theta_1)}{r_1 \cos \Theta_1}\right] d\tau_1\, d\tau_2\, d\tau_3$$

where

$\psi_3^*(1,2)$ = wave function for the $^3\Sigma_u$ state of H_2

$\psi_0(2,3)$ = wave function for the $^1\Sigma_g$ state of H_2

$$\psi_3^*(1,2) = \phi_{1sA} (1)\, \phi_{1sB} (2) \left[1+(\alpha\, Z_e^2)[X_A(1)X_B(2) + y_A(1)\, y_B(2)] + \beta Z_e^2[Z_A(1)Z_B(2)]\right]$$
$$- \phi_{1SA}(2)\, \phi_{1sB} (1) \left[1 + \alpha\, Z_e^2\, [X_A(2)\, X_B(1) + y_A(2)\, y_B(1)] + \beta\, Z_e^2[Z_A(2)\, Z_B(1)]\right] .$$

$\phi_{1sA} = \left(\frac{Z_e^3}{\pi}\right)^{1/2} e^{-Z_e r_{1A}}$; Z_e, α, c_3, β are constants; x_i, y_i, z_i are rectangular coordinates of electron centered on nucleus i. $\psi_0^{\,o}(2,3)$ is very similar to $\psi_3(1,2)$. The Θ_i's are angles involving the spherical polar angles θ, ϕ of the i^{th} particle.

The method to be used is to transform the integrand into rectangular coordinates centered at the midpoint of the internuclear axis of H_2, replace the infinite limits on the integrals with appropriate finite limits, scale the functions, and for a random set of coordinates evaluate the integrand. A random value for this integrand will be chosen and compared with the calculated value. This will be repeated enough times to evaluate the integral within 5-15%. The other integrals appearing in the problem are quite similar to the one listed and will be treated in a similar manner.

1380 Education. Reappraisal of Primary Mental Abilities. The purpose of this study is to take advantage of more sophisticated mathematical techniques and vastly improved computer facilities in appraising the technically crude but psychologically sophisticated classic study of L. L. Thurstone, Primary Mental Abilities, published in 1938. Mathematically, one is concerned with finding the cosines of angles between different bases for the same vector space. Using KSL 1.80 and 1.81, two such bases will be found. Using four already published other bases, all possible pairwise comparisons will be made. Each of the 30 such comparisons require solving for T in the matrix equation, $T = (A'A)^{-1}A'B$, where A and B are known and of order 57 x 13. This calculation may be carried out with KSL 5.00 and 5.10.

1381 Jewish Hospital, St. Louis, Missouri. Homogeneous Keying of Family Problems Scale. The problem is to complete construction of homogeneous scoring keys for the Family Problems Scale, a test composed of 213 dichotomous items. Tentative scoring keys have been worked out on the basis of item intercorrelations previously obtained. Routine scoring methods are not applicable, since each of the 5 scoring keys involves items on all three of the IBM cards for each subject, and since for each key the first alternative is scored for some items, the second alternative for others. After the 5 scores are obtained for each of about 270 persons, frequency distributions and intercorrelations will be obtained for these keys. Revision of the keys will be based on these data and on the point biserial correlation of each of the 213 items with each of the 5 keys.

1382 Psychology. Factor Analysis of Cancer Patient Data. The problem involves construction of 12 matrices of correlations of physiological data taken from 6 to 12 patients under treatment for prostatic cancer. Factor analysis will be taken of these 12 matrices and rotated to simple structure.

1383 Bureau of Economic and Business Research. Service Expenditure Analysis. A matrix of simple correlations for the purpose of analysis of service expenditures by household classifications will be studied. The K8 program will be used for this analysis.

1384 Psychology. Intercorrelations of D^2 Components. Various components of D^2-statistic have been calculated (means, variances, covariances, etc. -- there are nine components on each of three factors for each subject). The intercorrelations of these are desired. There are three such problems representing different degrees of independence of factors.

1385 T Agricultural Economics. Limited Information Estimate. The factors affecting price variations are to be extracted and studied.

1386 Electrical Engineering. Averaging and Sorting of Radio Bearings. The research problem involves the numerical analysis of quantities of measured information on the characteristics of ionospherically-propagated radio signals, especially the directional characteristics of these signals. The complexities of the propagation phenomena introduce errors in the measurements. Some of the errors are predictable, and some are not. (Predictable, as used here, implies that knowledge of the situation producing the error makes possible computation of the error.) There is some hope that statistical procedures will be useful in separating the non-predictable from the predictable error, and in using the predictable error for evaluating certain properties of the incoming signal.

The particular routines cataloged under this problem number are used for sorting and classifying measured data, both for ultimate use and in preparation for further processing.

Since the bulk of the data are to be partially or totally machine recorded, sample sizes tend to be large--too large to count manually, for example, as required for use with Library Routine K2. In addition, the number of samples will probably be large since it is contemplated to use these programs as "stock items" on several research contracts. Thus the amount of computer time involved is sufficient to make worthwhile the writing of a special program which will give just those answers most useful and which will be compatible with the form of the recorded data.

The four programs cataloged under Problem No. 1196 are designed for the following tasks:

1196a: From an original data tape, prepare a tape which will print out in a 3-column format the original data, the progressive mean, and a running-group mean, the size of the running group being specified in the data-tape heading.

1196b: Take the output tape from 1196a and prepare a tape for control of the Dataplotter to cause it to plot any of the three columns to a specified scale. (These would be time-series plots.)

1196c: From an original data tape, compute the mean, the RMS deviation from the mean, and the distribution function, and count the number of datum points in the sample.

1196d: From an original data tape, do essentially the same things as in 1196a and 1196b, but present the output on the CRT output of the Illiac. This routine would require much less computer time than 1196a and 1196b, and would suffice where the intermediate numerical output is not needed.

1387 Agronomy. Studies in Soybean Genetics. Analysis of variance will be the primary routines used. The objective is to study the genetics of the soybean plant for ultimate purpose of developing better varieties for Illinois. Illiac will be used for experimental data analysis.

1388 Speech. A Factor Analysis of the Observable Symptoms of Stage Fright. A considerable number of observable behaviors have been postulated as symptoms of stage fright. Measurements of "degree of intensity" of each of these observable behaviors were performed for 100 student speeches. The immediate question is whether this large number of behaviors may be grouped into a smaller number of related behavior classes. The most direct empirical approach calls for a factor analysis, for which regular Illiac routines exist.

1389 T Marketing. Service's Expenditures of the Aged. This study deals with the relationships between certain selected family characteristics and service's expenditures of the aged. The data used were taken from the 1950 Bureau of Labor Statistics Survey of Expenditures. A sample of 1756 families is being studied in respect to 20 variables. K15 will be used to analyze variance in relationships which appear to be significant. KSL 261 will be used to obtain a χ^2 value for contingency

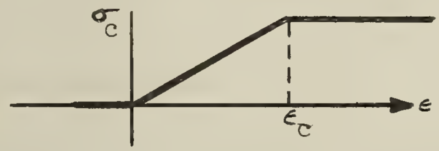
tables of family characteristics to ascertain if there is random order distribution or if one characteristic is related to another.

1390 Civil Engineering. Interaction Diagrams for Reinforced Concrete. If the relation between bending moment and unit rotation is known for a reinforced concrete section, several problems having to do with the stability and strength of a structural member having that particular cross section may be solved for any stage of loading. This particular problem involves the determination of unit rotation versus moment relationships for all combinations of axial load and moment which a prescribed cross section can be subjected to. Once these relationships are obtained for a range of steel area to concrete strength ratios, the weaknesses of R/c sections to various modes of failure can be easily demonstrated. The mathematical method is briefly described below:

x designates a position in the beam such that $0 \leq x \leq h$.

A linear strain distribution is prescribed over the depth of the beam .

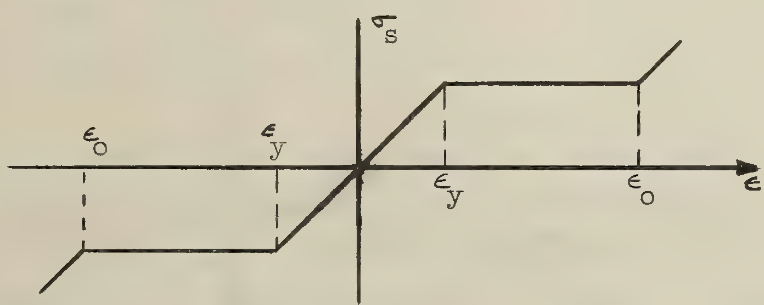
$P_1 = \int_{x=0}^{h} \sigma_c[\Sigma(x)]\,dx$ by routine F5, where $\sigma_c[\Sigma]$ is the σ-ϵ relationship for concrete and is computed by an auxiliary subroutine. A relationship of the following form is used.



The moment corresponding to this stress distribution is computed from

$$M_1 = \int_0^h x\,\sigma_c\,dx \quad .$$

The steel in the x-section of area $A_{,1} \ldots A_n$ at locations $x_1, \ldots x_n$, having the $\sigma_5\ \epsilon$ relationship



is introduced into the problem as

$$P = P_1 + \sum_{i=1}^{n} A_i \, \sigma_s[\epsilon(x_i)] \qquad \text{and}$$

$$M = M_1 + \sum_{i=1}^{n} x_i \, A_i \, \sigma_s[\epsilon(x_i)] \quad .$$

Print P and M with P19 (output for Dataplotter). Input or generate a new-strain distribution and repeat process. Resulting P-M graph is plotted on a PACE dataplotter.

1391 Animal Science. Physiological Effect of Estrogens in Cattle. This problem is to study the effect of estrogens (female sex hormones both natural and synthetic) on the hormone contact of the anterior pituitary of beef cattle and to relate the latter to the ability of the individual beef animal to gain weight. Since the number of beef animals studied is large and several assays had to be run on each animal, it is necessary to use least-squares analysis to study the differences.

1392 Electrical Engineering. Ray Path Propatation Parameters. The problem calculates the angles of a radio wave from artificial satellites with magnetic field, (x), and with the local vertical (i). It calculates also the value of cos x sec i for each point. The variables are:

1) geographic latitude
2) geographic differential longitude
3) height of satellite.

The calculated values are:

1) magnetic latitude
2) magnetic differential latitude
3) angular distance to a specific point (U. of I.)
4) cos x; angle of magnetic field with ray path
5) cos i; angle of local vertical with ray path
6) cos x sec i .

The procedure involves many trigonometric relations which are simple but laborious. The program consists of a straightforward application of such relations to a large number of points. The results will be used in interpretation of radio data received from artificial satellites, particularly in an evaluation of integral electron density. The required accuracy is 7 reliable figures.

1393 Electrical Engineering. Solution of Spherical Triangle. The problem consists of a solution of a spherical triangle, given three angles. The method is straight use of spherical formulas for triangles. The purposes are:

1) to test two subroutines for the "Ray path propagation parameters" program;

2) to calculate parameters for the "Ray propagation parameters" program which involves complex trigonometric functions with at least ten reliable figures. Trigonometric tables with more than 9 figures are not available in the University.

1394 Student Counseling Service. Prediction of Academic Success from Personality Test Score, for Different Levels of Scholastic Aptitude. Scores on a forced-choice personality scale and on scholastic-aptitude measures are to be correlated with grade-point averages at the end of the first semester for students of high, middle and low scholastic ability.

1395 T Physical Education. Underwater Demolition Team Research. The problem consists of a point biserial computation of 81 criteria to determine significant items present for passing or failing of the Navy's Underwater Demolition Team Training (modified product moment method correlation).

1396 T Psychology. Relation of Humor to Personality. A research problem in which the relationship is sought between responses to humor and independent measurements of personality and motivation. The analysis is largely correlational in nature. The following general steps will be made:

1) obtain a 78 by 78 product moment correlation matrix;

2) perform a Centroid Factor Analysis on this matrix (estimated communalities);

3) perform an analytic oblique rotation (oblimax) on the above results;

4) additional graphic rotations until simple structure is reached (using the Social Science Library routine for rotation and scope plotting).

Since the graphic rotation involves a successive approximation of simple structure, the exact time required is indeterminable. However, 5 to 7 such rotations would be a reasonable approximation based on previous work.

1397 T Animal Science. Meat Animal Carcass Evaluation. The object of this work is to evaluate correlations among various live-animal and carcass measurements and with certain physical and chemical values. This will be done by the method of least squares.

1398 T Marketing. The Uses of Socio-Economic Characteristics in Determining Income Level. The problem involves the choice of socio-economic characteristics which best estimate income level plus the derivation of the best form of the equation. Multiple regression techniques will be used in all forms of the equation. The Illiac will be used to compute these multiple regressions and also to compute the residuals.

1399 Psychology. A Cross Cultural Comparison of Factors in Child Training Practices. The purpose of the research is to compare the factors obtained from the analysis of child training practices in six different societies. The data consists of interviews with mothers from 6 different countries concerning their child training practices. These data were collected in connection with a cross cultural investigation of culture and personality. The data has already been factored using the Centroid Factoring Method and will be submitted in the form of 6 unrotated matrices. Each matrix contains from 32 to 35 variables, and each matrix has five factors. Each matrix will be rotated using both the Varimax (KSL 1.80) and the Oblimax (KSL 1.90) procedures. By rotating with both of these procedures it will be possible to compare the factors obtained by orthogonal and oblique rotations.

1400 Animal Science. Production Patterns of Hens Fed Varying Combinations of Two Proteins. Egg production over a period of 12 weeks as influenced by a number of diets is to be analyzed by the method of least squares.

1401 T Agricultural Economics. Resource Productivities on Farms in Relation to Farm Incomes and Type of Farming Areas in Illinois. The problem is to compute marginal productivities of resources on farms in each of two types of farming areas, a cash-grain area in East-Central Illinois, and an area in West-Central Illinois where livestock farming is predominant. It is to be determined what differences in

marginal productivities exist among the various classes of inputs within a given area, as well as what differences in marginal productivites are associated with differences in the type of farming areas and with differences in farm incomes. The study is designed to produce results which are particularly applicable to a farm credit study of which this project is a part. The Illiac will be used to solve standard regression equations, linear in logarithms, with nine and ten variables. The K14 or K16 routine should be applicable to this problem.

1402 T Computer. Magnetic Reversal. It is proposed to calculate the magnetic state of various square-loop multi-apertured ferromagnetic devices according to the Goodenough-Haynes flux reversal equation and attempt to develop methods of more accurate design calculation for such devices.

1403 Education. Factor Alpha-Reliability. Formulas have recently been developed for the alpha-reliability of factors, where factor is used generically to refer to a Thurstone common factor, Thurstone unique factor, Hotelling component generally, Hotelling principal component (eigenvector) particularly, and Guttman image factor. The Illiac may be used to give illustrative examples of the application of these formulas. In particular, evaluating these formulas requires extensive matrix multiplications.

1404 Psychology. Personality and Persuasibility. A. Nature of the data and computations needed consists of:

1) The data include 105 variables whose intercorrelations are needed. These are scores from 72 subjects on each variable. The first 94 variables are subjects' responses on self-rating personality items. Variables 95 to 100 are repeats of some earlier items, to serve as a reliability check. Variables 101 to 109 are composite scores, each made up by summarizing about 11 of the first 94 variables.

2) Correlations between the first 94 variables are needed for a subsequent factor analysis (see below); between these 94 and the next 6, for a reliability check; and between these 94 and the last 9, for item selection of those items which correlate highly with the total scale.

3) A Factor Analysis and Oblimax based on the intercorrelation of the first 94 items, to test hypotheses (see B, below) regarding the personality dimensions being measured by the items are then needed.

4) Finally, a Factor Analysis based on the 94 personality items plus 7 to 10 criterion opinion change measures is needed. (How many of these opinion change scores are to be employed depends to some extent on the outcome of the Factor Analysis under 2.)

B. General Nature of the research problem consists of:

1) The present study is designed to test a number of hypotheses regarding the relation of persuasibility to several personality characteristics.

2) 72 subjects were used. The original personality data consists of their responses to 94 items (these items were quadruple-choice, self-rating personality questions). According to the current hypotheses a Factor Analysis of these 94 response items should indicate 8 or 9 basic (non-orthogonial) factors (e.g., depression, neurotic anxiety, authoritarianism, self-esteem, etc.).

3) The data on the criterion variables (persuasibility) are based on the amount of opinion change on a series of issues from before to after receipt of persuasive communications of several different types. According to the current hypotheses, opinion change should be largely accounted for by two sets of factors, the person's "attention span" and his "gullibility". Other hypotheses relate the relative change produced by the different types of communications to certain predicted personality factors.

Social Science Library routines 1.20, Centroid Factor Analysis and Oblimax Rotations will be used in addition to the K8 routine.

Table I shows the distribution of Illiac machine time for the month of April.

TABLE I

	Hrs:Mins	
Regular Maintenance	22:57	
Unscheduled Maintenance	7:57	
Drum Engineering	25:25	
Leapfrog	27:53	
R.A.R.	4:23	
Library Development	4:40	
Wasted	3:07	
		96:22

Use by Departments

	Hrs:Min		
Computer	18:47		
Physics	30:07		
Control Systems Laboratory	60:23		
Structural Research	72:26		
Structural Research (AF 464)	16:09		
Civil Engineering (A.A.S.H.O. Road Test)	4:44		
Psychology	25:55		
Psychology (P.H. 1715)	:14		
Psychology (P.H. 1774)	:24		
Psychology (ONR 1834(11))	2:33		
Aviation Psychology (AF 49(638)371)	4:01		
Education	2:31		
Electrical Engineering	9:27		
Elect. Eng. (AF 6079)	2:37		
Elect. Eng. (NOBSR 64723)	1:25		
Elect. Eng. (BOEING)	1:07		
Elect. Eng. (NSFY 324026C)	:09		
Elect. Eng. (NSFG 67421)	:16		
Sociology	17:52		
Chemistry	73:09		
Agriculture	20:14		
Inst. of Com. Res.	:12		
Inst. of Com. Res. (9067C)	1:59		
College of Medicine	16:50		
Bureau of Educational Research	12:04		
Bur. of Educ. Res. (12-20-60-482)	:16		
Theor. and Appl. Mechanics (ORD 593 IC)	:28		
Economics	1:47		
Economics (NSFG 7056)	9:05		
Mechanical Engineering	:54		
Mech. Eng. (ORD 1980)	:47		
Min. and Met. Eng. (AF 3789)	:06		
Astronomy (NONR 1834(22))	1:12		
State Water Survey	1:35		
State Water Survey (46-26-84-312)	3:29		
Michael Reese Hospital, Chicago, Illinois	1:22		
Jewish Hospital, St. Louis, Missouri	:42		
University of North Carolina	:20		
Rhode Island University (Botany Department)	1:36		
Classes	24:12		
Demonstrations	1:20		
Miscellaneous	15:25		
		460:11	
			556:33

Error Frequency and Analysis

The Illiac is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared, using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:30-6:30 period (when the machine is checked), if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for April.

TABLE III

Williams Memory	2
Arithmetic	1
Drum	4
Punch	6
Reader	2
Scope	2
Power Supply	1
Other	2
Unknown	1
Total	21

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEER-ING	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/1/59	21:10	:00	2:50	0		:00	1:01	0
4/2/59	21:38	:28	1:54	3	1) Memory error 2) Tape tore in Reader I 3) Freon line in compressor broke	:00	1:37	0
4/3/59	23:10	:00	:50	0		:00	1:05	0
4/6/59	21:53	:00	2:07	0		:00	1:09	0
4/7/59	21:29	:00	2:31	0		:00	:39	0
4/8/59	23:19	:00	:41	0		:00	:44	0
4/9/59	22:17	:00	1:43	0		:00	:47	0
4/10/59	18:43	3:32	1:45	2	1) Scope error 2) Drum error	:00	:20	0
4/13/59	18:43	2:22	2:55	3	1) Running vs. Engineering time 2) Punch #1 error 3) Memory error	:00	:40	0
4/14/59	22:44	:00	1:16	0		:00	:20	0
4/15/59	22:24	:01	1:35	1	1) Drum error	:00	:44	0
4/16/59	22:43	:03	1:14	2	1) Scope error 2) Reader "J" error	:00	:40	0
4/17/59	23:38	:00	:22	0		:00	1:00	0
4/20/59	21:27	:00	2:33	0		:00	:40	0
4/21/59	21:39	:19	1:35	3	1) Drum error 2) Arithmetic error 3) +100 v power supply	:27	:54	0
4/22/59	19:20	2:22	2:18	4	1) Punch #3 error 2) Punch #3 error 3) Punch #1 error 4) Punch #1 error	:00	:56	0
4/23/59	20:29	:41	2:50	1	1) Drum error	:00	:41	0

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEER-ING	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
4/24/59	21:17	:00	2:43	0		:00	1:19	0
4/27/59	21:19	:00	2:41	0		:00	:51	0
4/28/59	21:12	:00	2:48	0		:00	:40	0
4/29/59	21:39	:00	2:21	0		:00	1:00	0
4/30/59	20:49	1:26	1:45	2	1) Punch #1 error 2) Unknown	:00	:40	0
TOTALS	473:02	11:14	43:17	21		:27	18:27	0

PART IV

IBM 650 USE AND OPERATION

During the month of April the IBM 650 was not operated since air conditioning has not yet been provided.

IBM 650 Library Routines

During the month of April three new routines were added to the 650 Library.

C2'-20' Address Search. This routine will search the drum for any word containing a specified address either in the data or instruction positions. Any such word will be printed on the on-line 407 accounting machine.

(R. H. Flenner)

P5'-21' Memory Dump on 407 with Zero Deletion. This routine will print the contents of the drum memory on the on-line 407 accounting machine. Runs of zeros will be omitted from this print. The routine may also be used as a Post Mortem dump of the drum memory.

(R. H. Flenner)

X5'-22' Load One to Seven Words Per Card from the 407 Unit. This routine loads cards from the on-line 407 accounting machine readfeed. The card format is identical to that used by routine X1'-1' which loads from the 533 readfeed.

(M. T. Gray)

IBM 650 Usage

During the month of April one new problem specification was submitted.

9' Theoretical and Applied Mechanics. Stress-Strain Curve From Bend Test. In the case of brittle fracture the behavior of prismatic beams is considerably different from that which would be predicted from the results of direct tension and compression

tests. Therefore, it is desired to determine the stress-strain curve which would be necessary to predict the actual behavior of a given prismatic beam. The solution of this problem for rectangular prisms may be reduced to the following equations:

$$\sigma_1 = \frac{2M + K\frac{\partial M}{\partial K}}{bh\frac{\partial \epsilon_1}{\partial K}} \qquad (1)$$

$$\sigma_2 = \frac{2M + K\frac{\partial M}{\partial K}}{bh\frac{\partial \epsilon_2}{\partial K}} \qquad (2)$$

where

σ_1 = the stress in the extreme tension fiber

σ_2 = the stress in the extreme compression fiber

ϵ_1 = the observed strain in the extreme tension fiber

ϵ_2 = the observed strain in the extreme compression fiber

M = the measured bending moment in the prism

$K = \frac{\epsilon_1 - \epsilon_2}{h}$ = the curvature of the prism

b = the width of the prism

h = the depth of the prism .

It is anticipated that the IBM 650 may be used to solve equations 1 and 2 either by first approximating M(K), $\epsilon_1(K)$, and $\epsilon_2(K)$ with the least mean squares fit of a polynomial or by performing a direct numerical differentiation of the observed values. The least mean squares approximation will be tried first since this simplifies the differentiation considerably.

Since the IBM computer is to be used to process the reduced data, the plan is to punch the raw data on IBM cards and use the 650 also to reduce the data. The routines for reducing the data will be extremely simple, but will add greatly to the speed and accuracy of data reduction.

PART V

GENERAL LABORATORY INFORMATION

Reports and Seminars

Reports

No. 87, "Calculation of Order Parameters in a Binary Alloy by the Monte Carlo Method", by Lloyd D. Fosdick.

Seminars

"Some Algorithms Appropriate for Large Scale Linear Programming Problems", by Professor R. L. Graves, University of Chicago, Chicago, Illinois, April 6.

"The Kinematic Analysis Program for Hydrogen Bubble Chamber Data Processing", by Dr. James N. Snyder, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, April 13.

"The Decision and Synthesis Problems in Semi-modular Circuit Theory", by James H. Shelly, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, April 20.

"Minimization Over Boolean Trees", by Dr. J. Paul Roth, IBM Research Center, Yorktown Heights, New York, April 27.

Personnel

The personnel associated with the department and, hence, the contributors to this report are:

Bahls, James E., Jr. Laboratory Mechanic
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Beardwood, Miss Jillian E., 1/2-time Research Assistant
Bivins, Robert L., 1/2-time Research Assistant
Blencoe, Robert W., Computer Operator I
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Clark, Miss Helen B., Secretary
Cummins, Richard L., Research Assistant
Dickman, Kern W., Research Assistant
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Murrell, T. A., Assoc. Prof. of Elec. Eng.
Naikelis, U. Stanley, 1/2-time Assistant
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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - MATHEMATICAL METHODS

PART III - ILLIAC USE AND OPERATION

PART IV - IBM 650 USE AND OPERATION

PART V - GENERAL LABORATORY INFORMATION

May, 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The Rich Electronic Computer Center at Georgia Institute of Technology is participating in this work by the support of a staff member at the University of Illinois.

1. Basic Circuits

Most of May was spent in preparing the remaining circuit drawings of the basic set, unifying the notation and enunciating the rules by which these circuits can be assembled into larger units. In particular the rules for matrix-design, fan-out and cascading have been finalized. Attention was also given to the problem of driving coaxial lines and to the decoupling between neighboring circuits. Two reports are being written, one covering the general design principles of our circuits and the other one the rules for logical and systems design.

(W. J. Poppelbaum and N. E. Wiseman)

The idea of creating the bumping voltages of +2.2v and -3.1v locally by the use of stabistors was tried and proved extremely successful. Figure 1 shows an output emitter follower using the new system. Both the long term drift and the transient behavior of the stabistors were such that the normal $\pm$.1v tolerance could be easily guaranteed. A slight temperature hysteresis of the stabistors did not appear harmful.

(J. W. Baur)

The idea of producing a one-collector-delay driver led to the design of a push-pull driver in which the (switching) output stages are driven by an input emitter-follower with a zener diode to produce the dc-shift in the positive direction. This is shown in Figure 2.

(W. J. Poppelbaum and N. E. Wiseman)

Complete drawings for a 52-bit shifting register with its associated control have been drawn up. Push-pull gating of F-elements is used throughout. The two controls suggested have theoretical shift-times (one up and one down shift) of 60mμs and 120mμs respectively. Provision has been made for hand sequencing of individual steps.

(W. J. Poppelbaum and N. E. Wiseman)

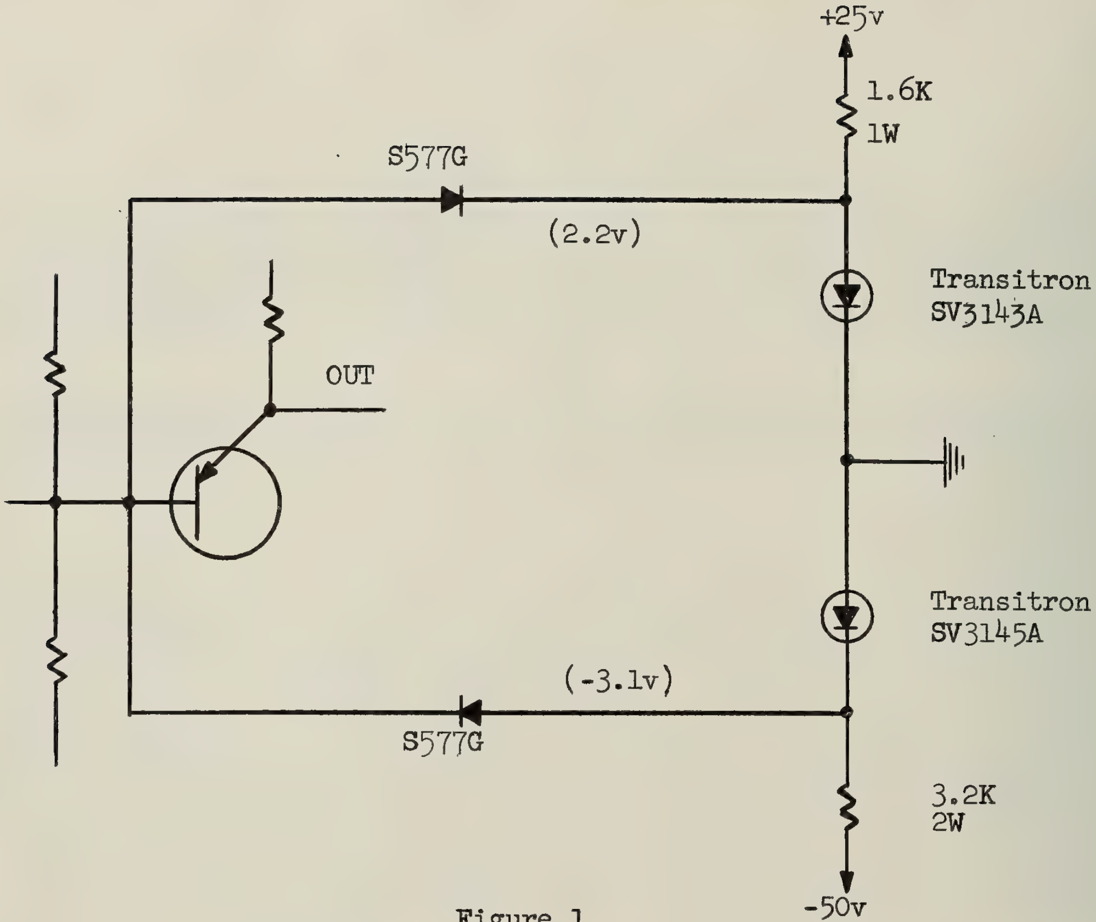

Figure 1

Local Creation of Bumps by Stabistors

Design work was also done to incorporate the last-moving-point system described in the TPR of September, 1958 into an F-element. This element behaves like the 2-collector delay element, but the difference amplifier connected to the sensing resistor produces a further collector delay.

(N. H. Johnson)

A report was written covering the transient behavior of transitors in both the emitter-follower and the grounded emitter connection. The wave-like propagation of signals in chains of emitter-followers and amplifiers was analyzed. One of the more important results of this investigation is the justification of emitter-follower-diode circuitry.

(T. Kunihiro)

The 9-bit flow-gating test unit was operated successfully with the driver design shown in last month's progress report. It is anticipated that with the presently designed end-equipment the goal of 100 mμs read time and 100 mμs write time can be attained.

(H. Guckel)

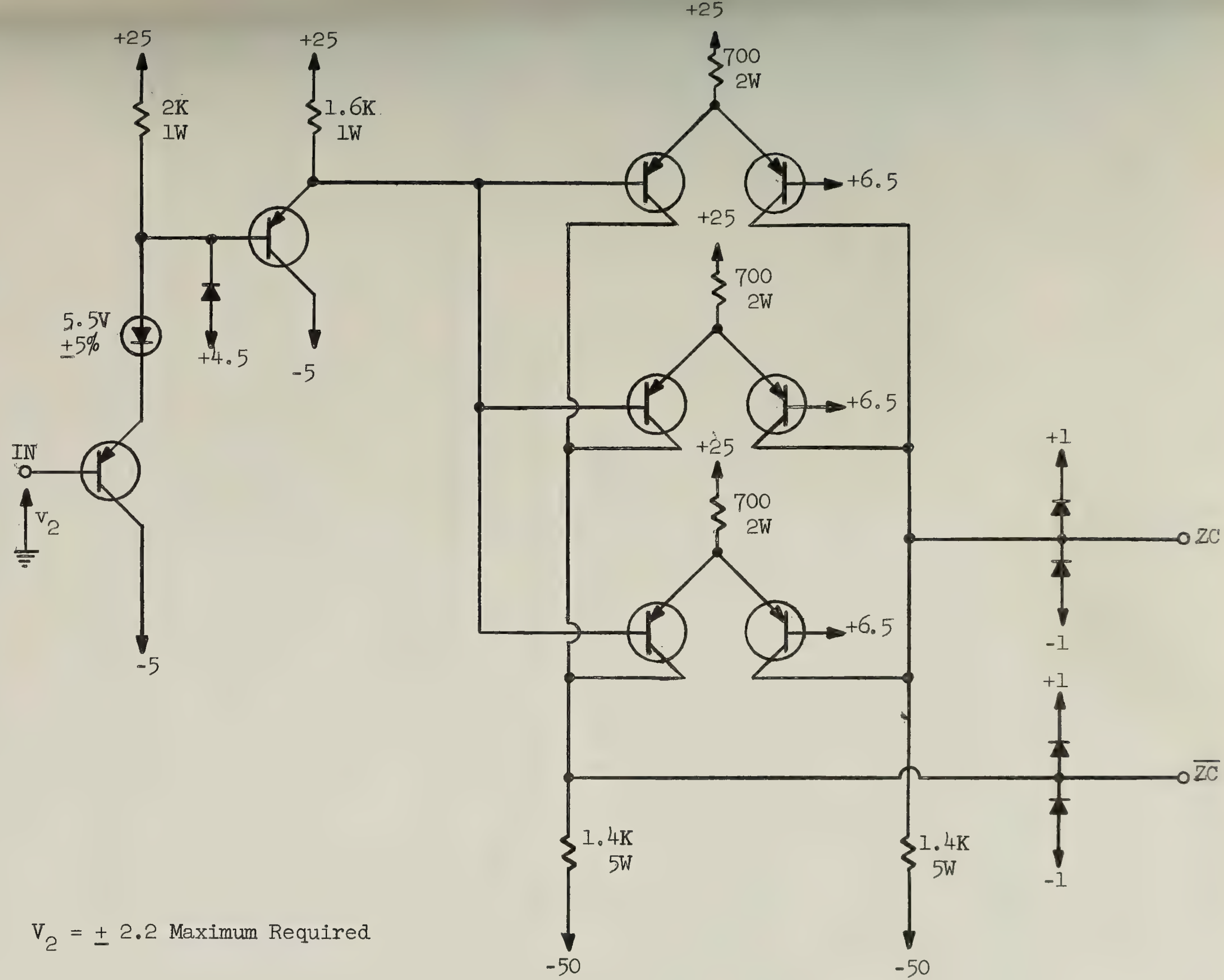

Figure 2

18 Bit Push Pull Driver with Zener Diode

2. Shifting Register Test Unit

On May 14 an error-free run was terminated after 547.6 hours in order to change power supplies. Another error-free run ended after 343.2 hours because of a campus-wide power failure on May 28, 1959.

3. Core Storage Unit

The question of the optimum value of resistance which is to be placed in series with the word line was studied this month. The effective inductance of a word line, L_W, was found to be 0.6μh when all bit cores are near the remanent induction for the presently proposed operating point. At the moment when the switch-core flux becomes exhausted following the WRITE operation, the word line current is approximately 300 ma due to the bit cores trying to return to the $H = 0$ condition along a reversible magnetization path. Thus, for the word line wire having 0.6Ω intrinsic resistance and an additional series resistance, R_s, the word line current is:

$$I_W = .3 \exp \left[- \frac{(R_s + .6)t}{.6 \cdot 10^{-6}} \right] \text{amp.}$$

with $t = 0$ taken as the moment of write-flux exhaustion.

Assuming that $t = 0.4\mu s$ corresponds to the next application of the read drive and that it is allowable that the circulating word-line current be as large as 100 ma at that time, it is found that $R_s \cong 1.05\Omega$. It remains to be seen whether the above assumptions are too strong or not. Note, however, that the circulating word-line current cannot grow from cycle to cycle because the bit cores fall back to $H = 0$ along, approximately, the same reversible path after exhaustion of the write flux. Thus the circulating current acts as an additional, but accurately predictable, tolerance on the read current and on the switching flux.

It is interesting to note that this circulating current is a problem (although a minor one) only in 2-core-per-bit word arrangement memories since the swamping resistance otherwise required in 1-core-per-bit types is relatively very large.

(S. Ray)

The design for a 1.5 amp. memory driver has been completed. The driver allows for a 30v swing on the collector of the driving transistor and will withstand a 20v backkick from switch cores returning to their biased state. The transistor complement is one each of: GF45011, 2N560, 2N546, ST400 plus one

additional ST 400 per block of drivers which are on only one at a time. One 125 w resistor is required per one of these extra ST 400's.

No ST 400's are as yet available to test, experimentally, the switching speed of this driver.

As this driver design now stands, there is a +17%, -8% current variation due to tolerances in resistors, power supplies, diodes, and transistor forward drops. If feedback is introduced, at the expense of an additional GF45011 and 2N601 per driver, but at the savings of the ST400 and high power resistor per block of drivers, it is felt that this current variability can be reduced. A design toward this end is now being calculated.

(John L. Muerle)

The memory timer design was tested for random variations in the pulse length. The variation in the time of the pulse was independent of the length of pulse, and amounted to between 2 and 8 mμs. The delay lines required in this design of timer must have fast rise times (30 or 40 mμs for 500 mμs delay), and an investigation of prices and availability of suitable units was started.

(J. D. Leslie)

Work was continued on the design of a memory read amplifier and error detection circuit. The design was completed and the circuit is presently being constructed for laboratory testing.

(A. B. Lindquist)

4. Tolerance Analysis

In the Technical Progress Report of this laboratory dated February, 1959, the first step in the development of a general automatic procedure for optimizing circuit parameter tolerances using the ILLIAC was described. The second step in this project is now nearly completed. This consisted of the writing of a program for the ILLIAC which solves for node voltages and branch currents for a circuit composed of resistors, diodes and transistors with prescribed supply voltages. This circuit analysis program will serve as an auxiliary subroutine for the optimizing program. A program currently in use, and known as the "General Tolerance Analysis Program (1206)" (See File No. 255 by G. H. Leichner) also solves for node voltages and branch currents but it was felt that this program which uses interpretive floating point and extensive drum transfers would be much too

slow to be used as a subroutine for the optimizing program. Since it seemed that such a high-speed circuit analysis program would be very useful in itself, it has been written as a complete program. Particular attention has been given to making it easy to use by persons having little or no experience with the ILLIAC. This program has been tested and checked except for that portion connected with transistor logic. After this program has been thoroughly tested, the appropriate modifications will be made and it will then be incorporated as a subroutine of the optimizing program. A brief description of the chief characteristics of this program are presented below.

The numerical method used for solving the circuit equations is different from that used in (1206) and is somewhat similar to the "iteration method" used for finding roots of non-linear equations. Let us consider some interior node of the circuit as shown in Figure 1, call it Node A, which is connected to four branches. Each branch may represent a resistance, or a diode, or the

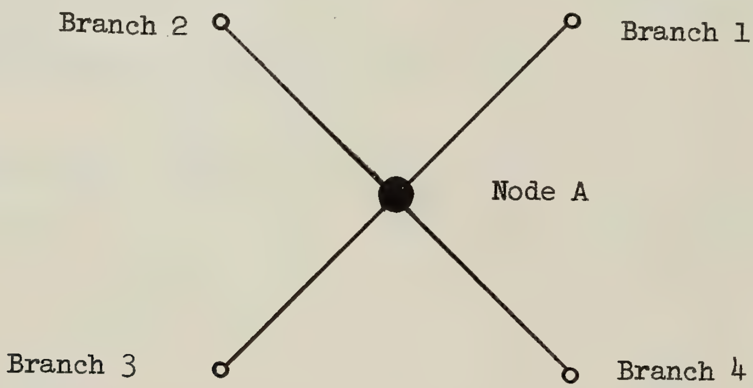

Figure 3

Interior Node, Connected to Four Branches

emitter, base, or collector of a transistor. Let us assume that Node A has a voltage V_A which is an estimate of the true voltage. The other nodes in the circuit likewise have voltage estimates assigned to them. The sum of the currents coming into Node A through branches 1, 2 and 3 is computed and the current in branch 4 is made the negative of this sum, thus forcing the sum of the currents into Node A to be zero. Now the voltage at A, call it V_A' which is necessary to produce this current in branch 4 is computed and the voltage estimate at A is corrected according to the formula:

$$V_A \text{ (corrected)} = V_A' + \lambda (V_A - V_A'), \tag{1}$$

where λ is a number between 0 and 1. A similar process is performed on the other interior nodes. Upon each new examination of a node, say Node A again, the branch which is selected for special consideration, as was branch 4 above, is changed in a systematic fashion; thus, on the next pass through the circuit branch 1 would be made to have the negative of the sum of the currents in branches 2, 3 and 4, etc. This iteration process continues until the maximum change on any node is less than some pre-assigned number. All of these calculations are performed in fixed point. This process has been tested on circuits with resistors only and is found to converge readily with $\lambda = 7/8$, but convergence difficulties appear when $\lambda = 1/2$. No studies with non-linear elements have been made yet. This technique of solution avoids calculation of derivatives and takes less storage space than would be required by the Newton-Raphson method.

To illustrate the format for the data tape and for the results we give a simple example, involving only resistors. The circuit is shown in Figure 4. Each node is assigned a letter

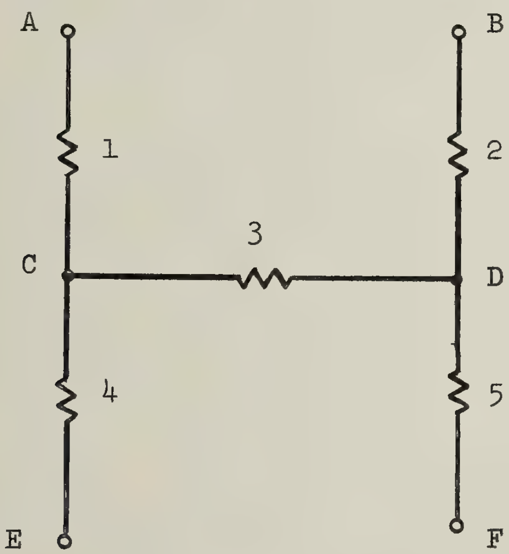

Figure 4

Circuit for Illustrative Example

(or a pair of letters may be used) and each branch is assigned a number (up to eleven digits). Nodes A, B, E and F represent supply voltages: V_A = 10 volts; V_B = 20 volts; V_E = -10 volts; V_F = -20 volts. The branches have the following resistance values: R_1 = 10K; R_2 = 20K; R_3 = 20K; R_4 = 40K; R_5 = 50K. The data

tape is made up as shown in Figure 5. The first two lines simply give identification numbers to the problem (identification number zero) and to the circuit (identification number two). The next five lines define the connections of the

```
PROBLEM 0
CIRCUIT 2
A, 1, C
B, 2, D
C, 3, D
C, 4, E
D, 5, F
TRANSISTORS
DATA 0
A,+00001,C
B,+00002,C
C,+000005,V
D,+000005,V
E,-00001,C
F,-00002,C
1,R,+01
2,R,+02
3,R,+02
4,R,+04
5,R,+05
END
```

Figure 5

Data Tape for Treating Circuit in Figure 4

nodes. Thus Node A connected to Node C by Branch 1 is indicated by A, 1, C and the sense of the current in this branch is prescribed by the ordering of A and C; it is understood positive, flowing from A to C. Following the word "TRANSISTORS" any transistor connections are specified: this is done by indicating the nodes connected to emitter, base, collector. Since no transistors are present, no such information is present. Following this the DATA are given (identified by the number zero here): the first line under DATA indicates that Node A has a voltage of .00001 megavolts, and "C" indicates that the voltage on this node is to be treated as a constant; the third line under DATA indicates that the initial guess for the voltage on C is .000005 megavolts, and V indicates that the voltage on this node is to be treated as a variable. Beginning with the seventh line under DATA information pertaining to the branches is given: thus, we have 1, R, +01 indicating that Branch 1 is a resistance of .01 megohms. If Branch 1 was a diode the letter "D" rather than "R" would appear and it would be followed by a number identifying the diode characteristic curve (held as a table among the program constants) for this diode. In circuits with

transistors, identifying data for the transistors would follow the branch data. This would consist of the identification number of the emitter-base curve and the α for the transistor. After all of this data the word END is printed. For the data tape shown in Figure 5, the program prints the solution shown in Figure 6.

```
PROBLEM 1
CIRCUIT 2
A, 1, C
B, 2, D
C, 3, D
C, 4, E
D, 5, F
TRANSISTORS
DATA   O                      SOLUTION
   A,+000010000000,C:    +000010000000
   B,+000019999999,C:    +000019999999
   C,+000005000000,V:    +000006814247
   D,+000005000000,V:    +000007856925
   E,-000010000000,C:    -000010000000
   F,-000019999999,C:    -000019999999
   1,R,+010000000000:    +000391832875
   2,R,+020000000000:    +000612450005
   3,R,+020000000000:    -000057430025
   4,R+040000000000:     +000402041767
   5,R,+049999999999:    +000555019980
```

Figure 6

Solution for Data Tape Shown in Figure 5

The complete data tape is reproduced on the output in a standard form. Under the word "SOLUTION" the voltages on each of the nodes, on the corresponding line appears, and the current (in amps) in each branch likewise appears on the appropriate line. In this example the end test on the iteration procedure was set such that a correction of less than 15% to the voltages on all the nodes in one iteration stopped the calculation. It should be remarked that a certain number of iterations is always made independent of this end test. This number is just equal to the number of branches connected to the node for which this number is greatest: thus, if the greatest number of branches entering any node in the circuit is ten, then it is guaranteed that ten complete passes through the circuit (i.e., iterations) will be made before the end test.

The following information is given to indicate storage space requirements. Let N_c be the number of constant nodes; let B_i be the number of branches

connected to the ith variable node, and let N_V be the number of variable nodes, and N_B be the total number of resistors, diodes and transistors, then the inequality

$$\sum_{i=1}^{N_V} (3 + 2B_i) + N_c + N_B + 3 < 300$$

must be satisfied. There is also enough space in the Williams Memory to hold two diode curves of twenty points each and two emitter-base curves of twenty points each. If additional curves are required they are stored on the drum. Unless these additional curves are required, the entire calculation is performed without accessing the drum (except for the input and output portion of the program) and therefore proceeds at maximum speed. If the curves from the drum are needed, then block transfers of this data to the Williams Memory are made as efficiently as possible.

The program has been arranged so that one can easily treat a series of problems in which the topology of the circuit remains constant and only certain of the parameter values change from one problem to the next.

A complete description of this program will be prepared after all of the tests have been made.

(L. Fosdick)

5. Auxiliary Storage

Revised drawings of the clock pulse generator circuit were sent to the shop for construction. Forward current vs. voltage curves were obtained experimentally for 10 units of Transitron stabistors, type S-320G, for possible use in the gate driving circuit of the pulse train generator.

(R. L. Cummins)

Tolerance analysis has been completed on the relay driver mentioned in previous reports. Design of a multiple "and" and "or" circuit, to be used in conjunction with a ring counter to produce a chain of pulses for experimenting with the Ampex tape transport, has been completed. Tolerance analysis on this circuit has been started.

(T. Piper)

A peak detection circuit was designed. Detection was accomplished by the resultant signal from the subtraction of the properly delayed read-back voltage from the read-back voltage. A bread-board set up was built and tested. The high-gain pre-amplifier was found not stable enough; a

slight ripple in the power supplies causes oscillations. Modifications are being made to improve its performance.

(C. Liu)

The writing circuit design using three 2N560 transistors, plus two GF 45011 transistors as preamplifiers, has been put into the shop and will be constructed. During the course of the design, the question of temperature effects arose, and a survey of both germanium and silicon devices was made. It was concluded that all temperature effects in germanium diodes and transistors can be taken into account by minor adjustments of tolerances. However, for silicon devices this may not be the case, since the operating temperature is over a considerably greater range, and several effects, notably the dependence of V_{EB} forward, beta, and switching speed, are somewhat larger. It is proposed that two standard tolerance analyses be carried out for circuits using silicon devices, one at room temperature and the other at the maximum operating temperature.

(T. A. Murrell)

6. Arithmetic Unit

A study of implementing the division operation is in process. Particular attention is being given to the general approach described in Report 82, "A New Class of Digital Division Methods," because it permits leaving the partial remainder in unassimilated form during the iterative part of the operation, thereby making optimum use of existing equipment. In order to remove the restriction that the quotient be $<2/3$ in magnitude (a result applying to the relations developed in Report 82 for a base 4 representation), the dividend is treated as the initial shifted partial remainder, and the number of iterative steps is increased by 1 to compensate. Several other minor questions of procedure are contingent on details of the arithmetic unit layout which are currently being decided.

In connection with division, attention is also being given to the shift counter and exponent arithmetic unit, with the possibility of merging the two operations hardware-wise being investigated. Several designs of adders using matrix circuits were also investigated.

(R. Shively)

ERRATA

In the April Technical Progress Report, Figure 1 on page 2 in in error in the following ways: emitter follower collector resistors marked 10K, 1/10 W should be 10 Ω, and resistors marked 780K, 1W and 860K, 1W should be 780 Ω and 860 Ω respectively.

PART II

MATHEMATICAL METHODS

1. Equations of Hydrodynamics (Supported in part by the Office of Naval Research under Contract Nonr-1834(27).)

An analysis has been made of the method employed by Harlow of the Los Alamos Scientific Laboratory for integrating the equations describing a hydrodynamic flow with shocks. This method has been compared with methods that may be obtained from the formulation of the conservation laws given by Taut. As a result of this comparison, some understanding of the nature of the approximations made by Harlow has been achieved and other simpler approximations have been suggested.

(R. L. Bivins)

2. Calculation of Order Parameters in a Simple Cubic Ising Lattice by the Monte Carlo Method

The results of a study of order-disorder in the simple cubic Ising Lattice by the Monte Carlo method are presented below. These results were obtained from an ILLIAC program known as INCUBUS (see File No. 254).

In Table 1 the results for the ferromagnetic case are presented. The quantity K appearing in the first column is the coupling energy for first neighbors divided by kT (k = Boltzmann's constant and T is the absolute temperature) and the quantity L appearing in the second column represents the coupling to the external magnetic field divided by kT. Hence, if E is the total energy of the system, and N_{o1} the number of antiparallel first neighbors, N_o the number of spins "up" and N_1 the number of spins "down", then

$$\frac{E}{kT} = 2K\, N_{o1} + L\,(N_1 - N_o).$$

In the third column the average of the long-range order is presented,

$$S = \frac{|N_1 - N_o|}{N_1 + N_o}.$$

The indicated spread is the standard deviation of the mean. In the next two columns the mean values of the fraction of antiparallel first neighbor spins, $p_{o1}^{(1)}$, and antiparallel second neighbor spins, $p_{o1}^{(2)}$, are presented along with the standard deviations. The last three columns give the number of initial iterations before the convergence test is made, the total number of configurations making up the sample used in the averaging, and finally the number of

extra passes or iterations that had to be performed in addition to the initial N before the convergence test conditions were satisfied. The convergence test is made by performing the Monte Carlo iteration process simultaneously on two independent lattices, one of the lattices being given an initial configuration of complete order, the other of complete disorder (i.e., random) and comparing the values of $p_{ol}^{(1)}$ and $p_{ol}^{(2)}$ for the two lattices where the sample consists of the last N configurations. As soon as both results for the two lattices agree to within 2%, M-N additional configurations are generated and the resultant sample is used to calculate the averages in this table. In all cases the lattice had dimensions of 8 x 8 x 8 (i.e., 512 spins in all). The same results for the antiferromagnetic case are given in Table 2. These results are presented in graphical form in Figures 5, 6, and 7.

A complete report of this work is now being prepared for publication.
(L. Fosdick)

TABLE I

SUMMARY OF RESULTS FOR FERROMAGNETIC (K > 0) CASE

K	$\bar{L}$	S	$\bar{p}_{ol}^{(1)}$	$p_{ol}^{(2)}$	N	M	Extra Passes
0.125	0	0.0563 $\pm$0.0030	0.4329 $\pm$0.0007	0.4818 $\pm$0.0006	50	100	0
0.143	0	0.0686 $\pm$0.0018	0.4211 $\pm$0.0004	0.4755 $\pm$0.0003	100	400	0
0.167	0	0.0819 $\pm$0.0022	0.4047 $\pm$0.0005	0.4639 $\pm$0.0005	100	400	0
0.200	0	0.160 $\pm$0.004	0.3713 $\pm$0.0007	0.4344 $\pm$0.0008	100	400	0
0.217	0	0.3054 $\pm$0.0123	0.3301 $\pm$0.0026	0.3891 $\pm$0.0033	50	100	0
0.227	0	0.4976 $\pm$0.0090	0.2841 $\pm$0.0024	0.3315 $\pm$0.0031	50	100	16
0.238	0	0.6551 $\pm$0.0060	0.2286 $\pm$0.0024	0.2623 $\pm$0.0029	50	100	61
0.250	0	0.744 $\pm$0.002	0.185 $\pm$0.001	0.210 $\pm$0.001	100	400	0
0.285	0	0.8653 $\pm$0.0060	0.1073 $\pm$0.0021	0.1181 $\pm$0.0026	50	100	2

TABLE I (Continued)

K	L	S	$p_{ol}^{(1)}$	$p_{ol}^{(2)}$	N	M	Extra Passes
0.338	0	0.9424 ±0.0011	0.0516 ±0.0006	0.0549 ±0.0007	100	400	3
0.125	0.0625	0.1834 ±0.0052	0.4203 ±0.0009	0.4670 ±0.0008	50	100	0
0.167	0.0625	0.3284 ±0.0071	0.3678 ±0.0018	0.4179 ±0.0021	50	100	0
0.200	0.625	0.5529 ±0.0062	0.2847 ±0.0024	0.3237 ±0.0028	50	100	0
0.227	0.0625	0.7354 ±0.0044	0.1958 ±0.0021	0.2192 ±0.0025	50	100	1
0.250	0.0625	0.8184 ±0.0032	0.1449 ±0.0017	0.1599 ±0.0020	50	100	2
0.125	0.125	0.3415 ±0.0045	0.3880 ±0.0013	0.4286 ±0.0014	50	100	0
0.167	0.125	0.5303 ±0.0050	0.3084 ±0.0019	0.3445 ±0.0022	50	100	0
0.200	0.125	0.6917 ±0.0053	0.2249 ±0.0023	0.2502 ±0.0028	50	100	0
0.217	0.125	0.7678 ±0.0054	0.1788 ±0.0024	0.1972 ±0.0028	50	100	0
0.227	0.125	0.8094 ±0.0025	0.1533 ±0.0014	0.1681 ±0.0017	50	100	27
0.238	0.125	0.8383 ±0.0022	0.1340 ±0.0013	0.1459 ±0.0015	50	100	5
0.250	0.125	0.8683 ±0.0023	0.1116 ±0.0014	0.1210 ±0.0016	50	100	5
0.125	0.25	0.5655 ±0.0034	0.3082 ±0.0015	0.3341 ±0.0016	50	100	0
0.200	0.25	0.8127 ±0.0024	0.1548 ±0.0014	0.1670 ±0.0016	50	100	2
0.238	0.25	0.8966 ±0.0018	0.0909 ±0.0012	0.0969 ±0.0013	50	100	3

TABLE I (Continued)

K	L	S	$p_{ol}^{(1)}$	$p_{ol}^{(2)}$	N	M	Extra Passes
0.285	0.25	0.9390 $\pm$0.0013	0.0562 $\pm$0.0009	0.0587 $\pm$0.0010	50	100	9
0.050	1.25	0.9053 $\pm$0.0014	0.0902 $\pm$0.0014	0.0911 $\pm$0.0014	50	100	0
0.200	1.25	0.9834 $\pm$0.0007	0.0163 $\pm$0.0005	0.0165 $\pm$0.0005	50	100	1
0.338	1.25	0.9921 $\pm$0.0004	0.0078 $\pm$0.0003	0.0079 $\pm$0.0003	50	100	1

TABLE II

SUMMARY OF RESULTS FOR ANTIFERROMAGNETIC ($K < 0$) CASE

K	L	S	$p_{ol}^{(1)}$	$p_{ol}^{(2)}$	N	M	Extra Passes
-0.050	0.25	0.1964 $\pm$0.0038	0.5056 $\pm$0.0007	0.4798 $\pm$0.0006	50	100	0
-0.100	0.25	0.1566 $\pm$0.0038	0.5394 $\pm$0.0007	0.4785 $\pm$0.0007	50	100	0
-0.150	0.25	0.1264 $\pm$0.0040	0.5729 $\pm$0.0008	0.4674 $\pm$0.0008	50	100	0
-0.200	0.25	0.1030 $\pm$0.0037	0.6171 $\pm$0.0013	0.4366 $\pm$0.0015	50	100	0
-0.250	0.25	0.0564 $\pm$0.0014	0.7960 $\pm$0.0024	0.2224 $\pm$0.0029	50	100	22
-0.350	0.25	0.0173 $\pm$0.0007	0.9504 $\pm$0.0010	0.0519 $\pm$0.0011	50	100	6
-0.050	1.25	0.7670 $\pm$0.0020	0.2103 $\pm$0.0012	0.2065 $\pm$0.0012	50	100	0
-0.100	1.25	0.6778 $\pm$0.0023	0.2840 $\pm$0.0011	0.2697 $\pm$0.0011	50	100	0
-0.150	1.25	0.5852 $\pm$0.0027	0.3578 $\pm$0.0011	0.3239 $\pm$0.0009	50	100	0
-0.200	1.25	0.5016 $\pm$0.0033	0.4261 $\pm$0.0012	0.3598 $\pm$0.0008	50	100	0

TABLE II (Continued)

K	L	S	$p_{ol}^{(1)}$	$p_{ol}^{(2)}$	N	M	Extra Passes
-0.250	1.25	0.4221 $\pm$0.0035	0.4960 $\pm$0.0013	0.3754 $\pm$0.0008	50	100	0
-0.300	1.25	0.3131 $\pm$0.0022	0.6216 $\pm$0.0026	0.3169 $\pm$0.0023	50	100	29
-0.500	1.25	0.0298 $\pm$0.0007	0.9686 $\pm$0.0006	0.0307 $\pm$0.0006	50	100	34

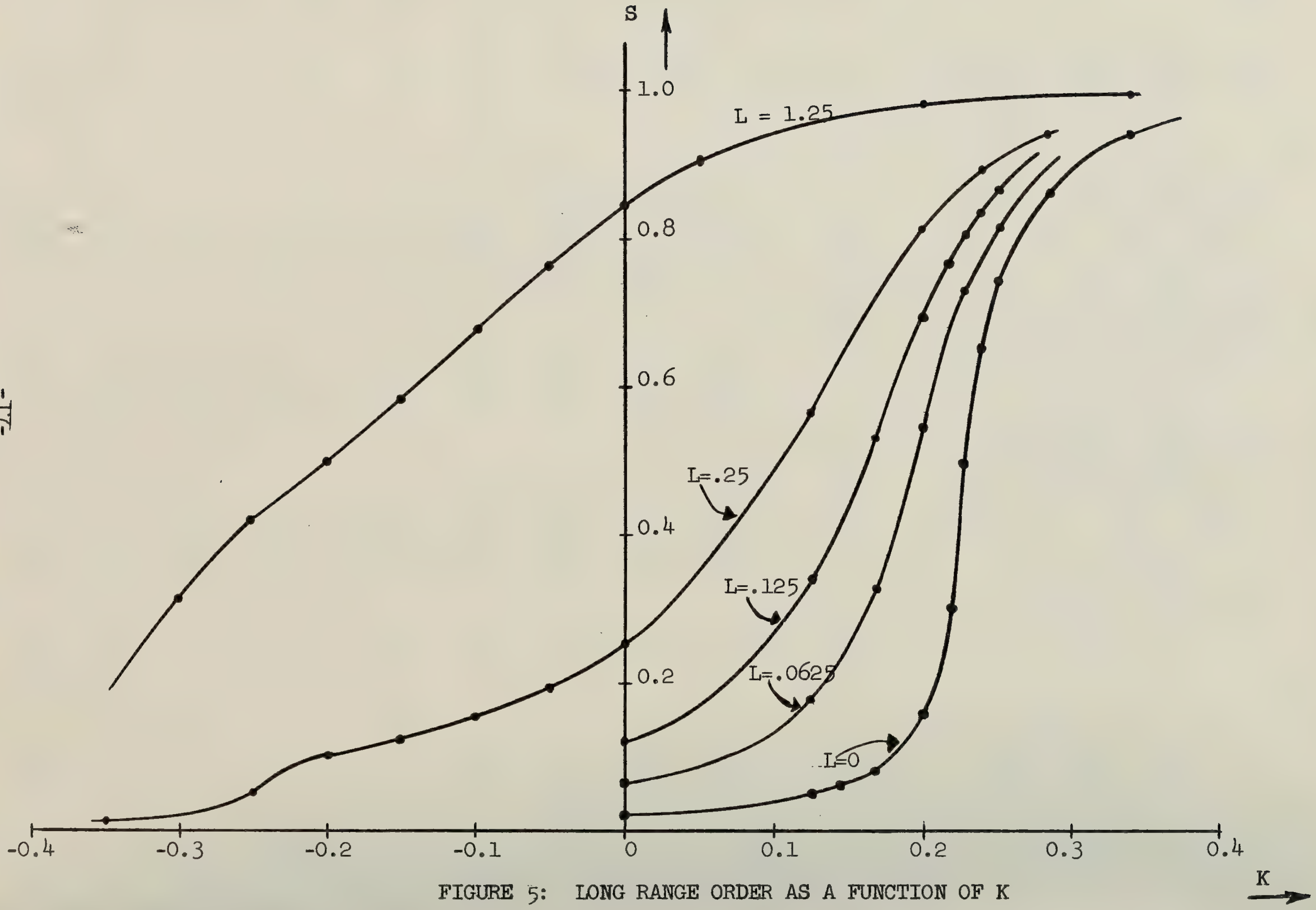

FIGURE 5: LONG RANGE ORDER AS A FUNCTION OF K

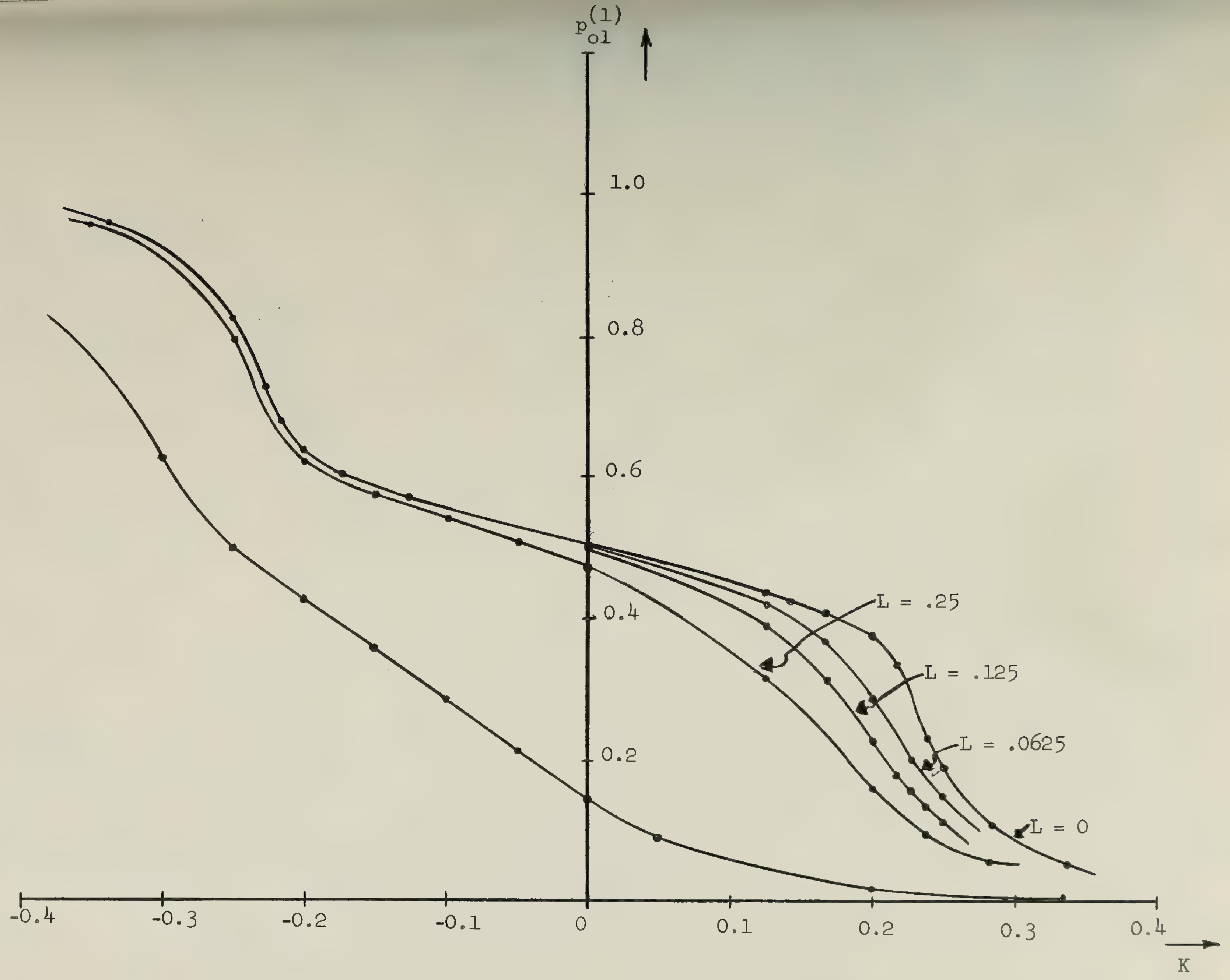

FIGURE 6: FIRST NEIGHBOR ORDER AS A FUNCTION OF K

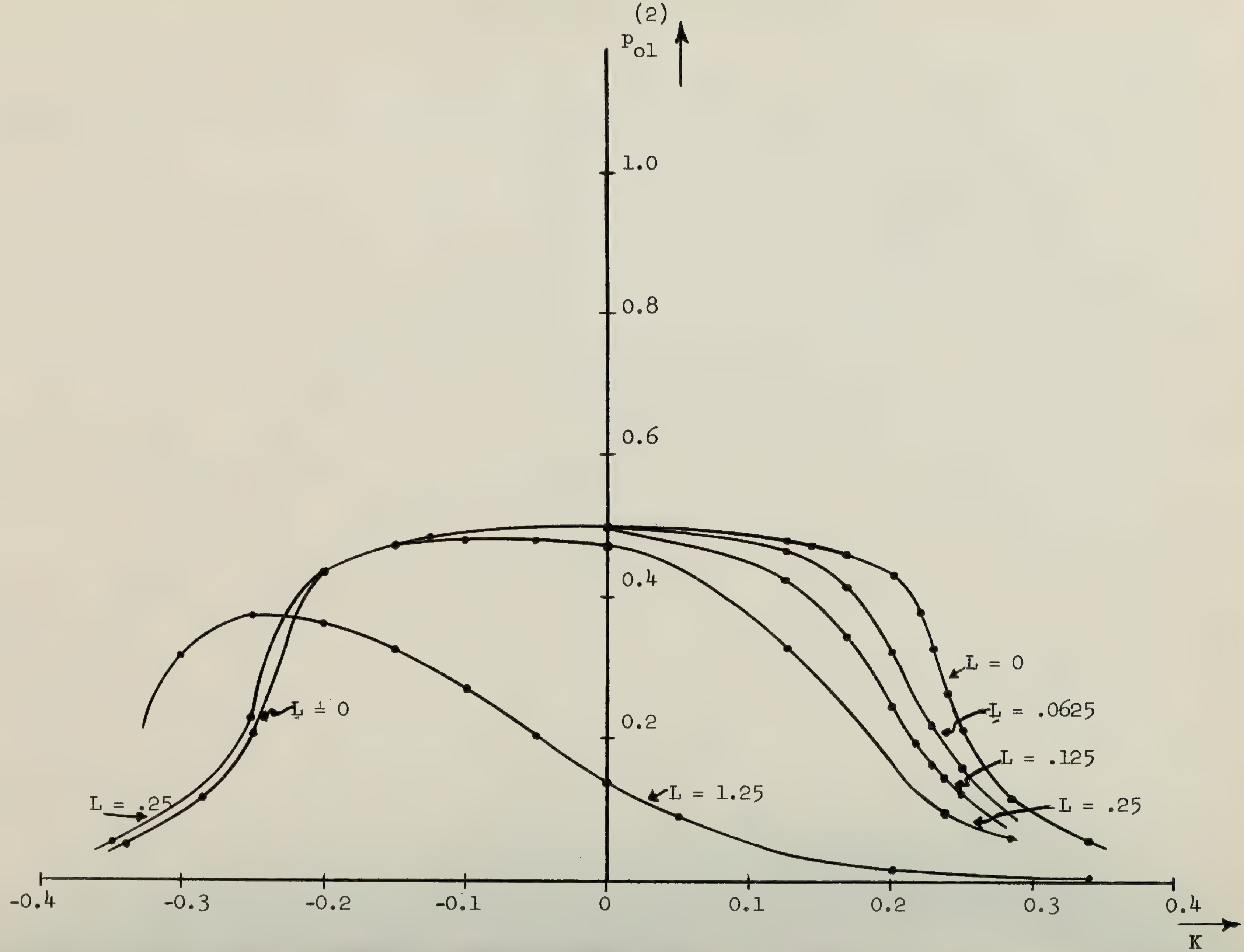

FIGURE 7: SECOND NEIGHBOR ORDER AS A FUNCTION OF K

3. Calculation of Order Parameters in a Body Centered Cubic Ising Lattice by the Monte Carlo Method

The results of a study of order-disorder in the body centered cubic Ising lattice are presented below. These results were obtained from an ILLIAC program known as SPINNAKER (see Technical Progress Report, October, 1958).

The results are presented in two tables in a form similar to those in the preceding section for the simple cubic lattice. In these calculations the results for the two independent lattices, used in the convergence testing, have not been combined and are presented separately. Some experimenting was done with different sizes of lattice as indicated in the tables. In a couple of the runs, indicated by †, the sites of the lattice were picked randomly rather than systematically, which was the method used in all of the other runs. The results are plotted in Figures 8, 9, and 10. In Figures 8 and 9 the continuous curves correspond to constant L and the broken curves to constant L/K (i.e., constant external magnetic field). Results obtained by evaluating Wakefield's series are indicated for comparison. In Figure 10 the Monte Carlo results are compared with those of Bethe's second approximation method and experimental measurements made by Chipman and Warren on β-brass (the order disorder problem in β-brass is formally equivalent to the Ising lattice problem treated here). In this figure all results have been normalized to give the same Curie Temperature.

A complete report of this work is now being prepared for publication.

(L. Fosdick and D. Handscomb)

TABLE III

SUMMARY OF RESULTS FOR FERROMAGNETIC CASE

K	L	S	$p_{ol}^{(1)}$	Unit Cells in Lattice	N	M	Extra Passes
.05	0	.0453 ± .0062 .0318 ± .0024	.4684 ± .0026 .4767 ± .0018	8 x 8 x 8	50	100	1
.1	"	.0441 ± .0038 .0484 ± .0036	.4404 ± .0012 .4430 ± .0010	"	"	"	0
.125	"	.0784 ± .0071 .0684 ± .0051	.4179 ± .0017 .4223 ± .0013	"	"	"	0

TABLE III (Continued)

K	L	S	$p_{ol}^{(1)}$	Unit Cells in Lattice	N	M	Extra Passes
.1375	0	.0938 ± .0095 .1091 ± .0071	.4030 ± .0023 .4099 ± .0013	8 x 8 x 8	50	100	0
.15	"	.2159 ± .0132 .1602 ± .0101	.3734 ± .0027 .3850 ± .0017	"	"	"	1
" †	"	.1383 ± .0109 .2115 ± .0103	.3854 ± .0023 .3834 ± .0020	"	20	50	48
"	"	.1792 ± .0281 .0234 ± .0062	.3821 ± .0027 .3881 ± .0014	16 x 16 x 16	7	12	4
.1625	"	.5216 ± .0091 .5246 ± .0103	.2981 ± .0033 .2982 ± .0032	8 x 8 x 8	50	100	0
" †	"	.4941 ± .0121 .3822 ± .0187	.3081 ± .0044 .3297 ± .0043	"	20	50	60
"	"	.5380 .2472	.2925 .3353	16 x 16 x 16	7	12	*(12)
.175	"	.6884 ± .0050 .6697 ± .0102	.2251 ± .0027 .2321 ± .0035	8 x 8 x 8	50	100	9
.1875	"	.8023 ± .0028 .7850 ± .0095	.1607 ± .0018 .1662 ± .0034	"	"	"	1
.225	"	.9067 ± .0019 .9032 ± .0032	.0831 ± .0015 .0847 ± .0016	"	"	"	3
.3	"	.9804 ± .0007 .9800 ± .0018	.0189 ± .0007 .0188 ± .0012	"	"	"	1
.05	"	.1031 ± .0098 .1169 ± .0074	.4635 ± .0036 .4714 ± .0022	4 x 4 x 4	50	100	0
.1	"	.1366 ± .0103 .1433 ± .0107	.4430 ± .0030 .4376 ± .0029	"	"	"	0
.175	"	.7127 ± .0109 .6717 ± .0202	.2173 ± .0063 .2251 ± .0088	"	"	"	0
.225	"	.8966 ± .0060 .8931 ± .0129	.0908 ± .0045 .0866 ± .0004	"	"	"	0

* This run showed no sign of convergence within the allotted time.

† These runs were performed with random sequencing.

TABLE III (Continued)

K	L	S	$p_{ol}^{(1)}$	Unit Cells in Lattice	N	M	Extra Passes
.1	.05	.1530 + .0076 .1516 ± .0094	.4351 ± .0014 .4330 ± .0023	8 x 8 x 8	20	50	0
.125	"	.3135 ± .0102 .3165 ± .0130	.3869 ± .0027 .3853 ± .0039	"	"	"	0
.15	"	.6190 ± .0093 .6018 ± .0073	.2715 ± .0042 .2769 ± .0036	"	"	"	0
.1625	"	.7136 ± .0056 .7137 ± .0052	.2190 ± .0032 .2185 ± .0030	"	"	"	6
.2	"	.8809 ± .0029 .8823 ± .0031	.1044 ± .0023 .1030 ± .0024	"	"	"	8
.05	.15	.2338 ± .0064 .2349 ± .0066	.4517 ± .0018 .4472 ± .0016	"	"	"	0
.1	"	.4388 ± .0077 .4441 ± .0086	.3652 ± .0031 .3632 ± .0033	"	"	"	0
.125	"	.6051 ± .0062 .6113 ± .0063	.2857 ± .0034 .2836 ± .0030	"	"	"	3
.15	"	.7657 ± .0047 .7663 ± .0047	.1906 ± .0031 .1902 ± .0028	"	"	"	1
.05	.25	.3789 ± .0055 .3712 ± .0069	.4089 ± .0023 .4108 ± .0024	"	"	"	0
.1	"	.6084 ± .0052 .6056 ± .0053	.2905 ± .0029 .2946 ± .0030	"	"	"	0
.125	"	.7361 ± .0047 .7379 ± .0042	.2130 ± .0032 .2119 ± .0027	"	"	"	0
.15	"	.8371 ± .0034 .8338 ± .0034	.1416 ± .0025 .1430 ± .0024	"	"	"	1
.05	.35	.4970 ± .0051 .4943 ± .0049	.3621 ± .0025 .3613 ± .0024	"	"	"	0
.1	"	.7105 ± .0042 .7164 ± .0040	.2329 ± .0027 .2293 ± .0026	"	"	"	0
.125	"	.8135 ± .0034 .8076 ± .0040	.1596 ± .0026 .1649 ± .0029	"	"	"	0

TABLE III (Continued)

$\underline{K}$	$\underline{L}$	$\underline{S}$	$p_{ol}^{(1)}$	Unit Cells in Lattice	$\underline{N}$	$\underline{M}$	Extra Passes
.15	.35	.8718 ± .0033 .8795 ± .0027	.1143 ± .0026 .1081 ± .0023	8 x 8 x 8	20	50	0
.175	"	.9222 ± .0037 .9198 ± .0020	.0720 ± .0030 .0741 ± .0018	"	"	"	0
.05	1.0	.8729 ± .0025 .8725 ± .0025	.1174 ± .0021 .1180 ± .0022	"	"	"	5

TABLE IV

SUMMARY OF RESULTS FOR ANTIFERROMAGNETIC CASE

K	L	S	$p_{ol}^{(1)}$	Unit Cells in Lattice	N	M	Extra Passes
-.05	.35	.2451 ± .0060 .2463 ± .0085	.4922 ± .0023 .4916 ± .0018	8 x 8 x 8	20	50	0
-.1	"	.1849 ± .0050 .1870 ± .0059	.5304 ± .0020 .5361 ± .0017	"	"	"	0
-.15	"	.1387 ± .0033 .1360 ± .0028	.5954 ± .0021 .6010 ± .0034	"	"	"	1
-.2	"	.0681 ± .0024 .0646 ± .0021	.8300 ± .0050 .8501 ± .0028	"	"	"	13
-.25	"	.0296 ± .0011 .0268 ± .0015	.9386 ± .0047 .9461 ± .0017	"	"	"	1
-.1	1.0	.5127 ± .0067 .5133 ± .0088	.3947 ± .0044 .3945 ± .0063	"	"	"	0
-.15	"	.4107 ± .0056 .4119 ± .0074	.4715 ± .0036 .4738 ± .0044	"	"	"	0
-.2	"	.2704 ± .0035 .2734 ± .0028	.6472 ± .0055 .6472 ± .0037	"	"	"	6
-.25	"	.1299 ± .0038 .1222 ± .0025	.8472 ± .0054 .8604 ± .0028	"	"	"	2
-.3	"	.0655 ± .0066 .0548 ± .0016	.9247 ± .0091 .9409 ± .0016	"	"	"	0
-.2	2.0	.6734 ± .0057 .6728 ± .0064	.2991 ± .0051 .3002 ± .0055	"	"	"	0
-.25	1.25	.2003 ± .0078 .1921 ± .0025	.7744 ± .0091 .7877 ± .0028	"	"	"	0
-.05	.5	.3431 ± .0057 .3467 ± .0065	.4591 ± .0025 .4601 ± .0157	"	"	"	0
-.15	.75	.3060 ± .0054 .3044 ± .0036	.5278 ± .0032 .5321 ± .0167	"	"	"	0

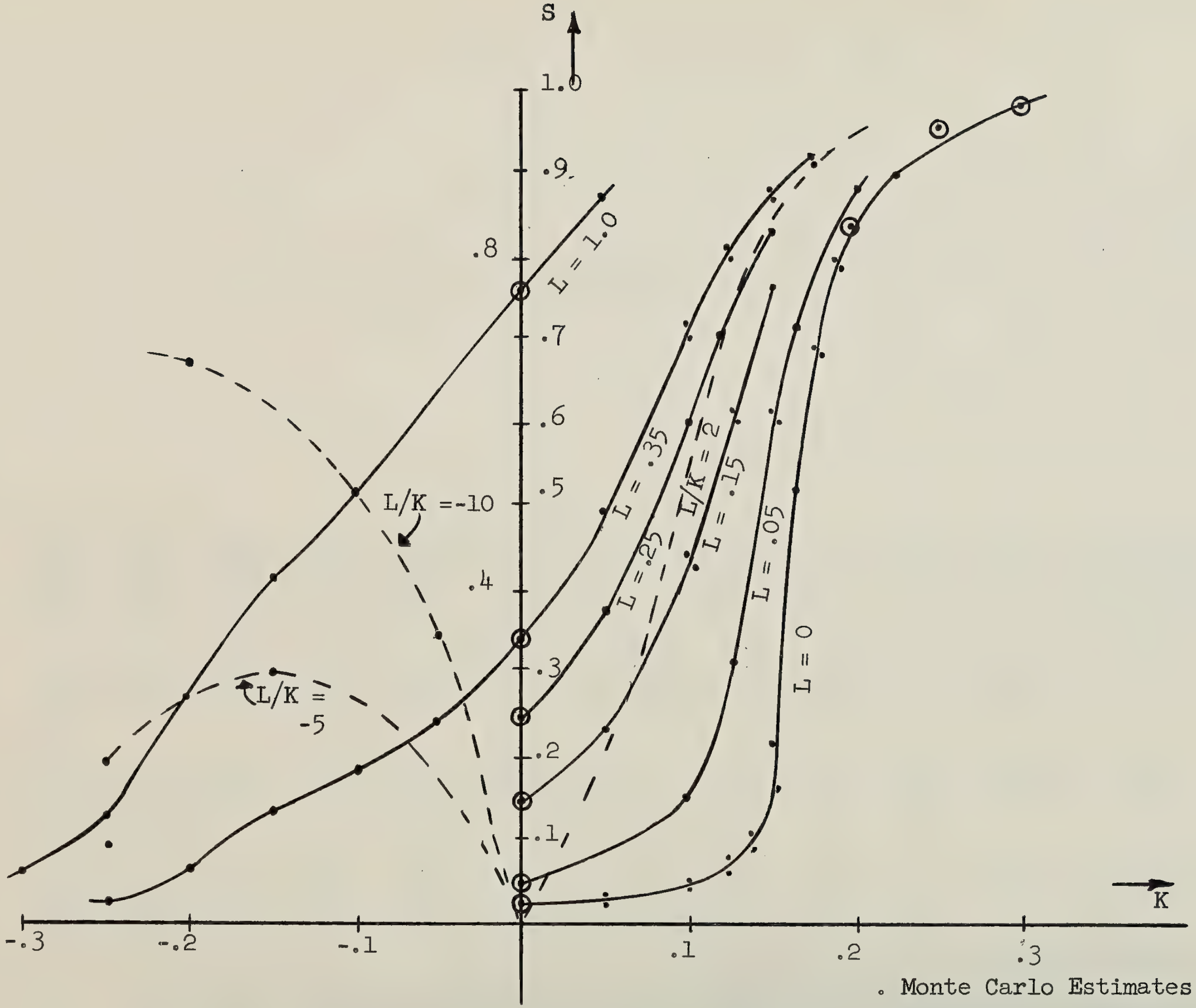

Figure 8: Long-Range Order as a Function of K

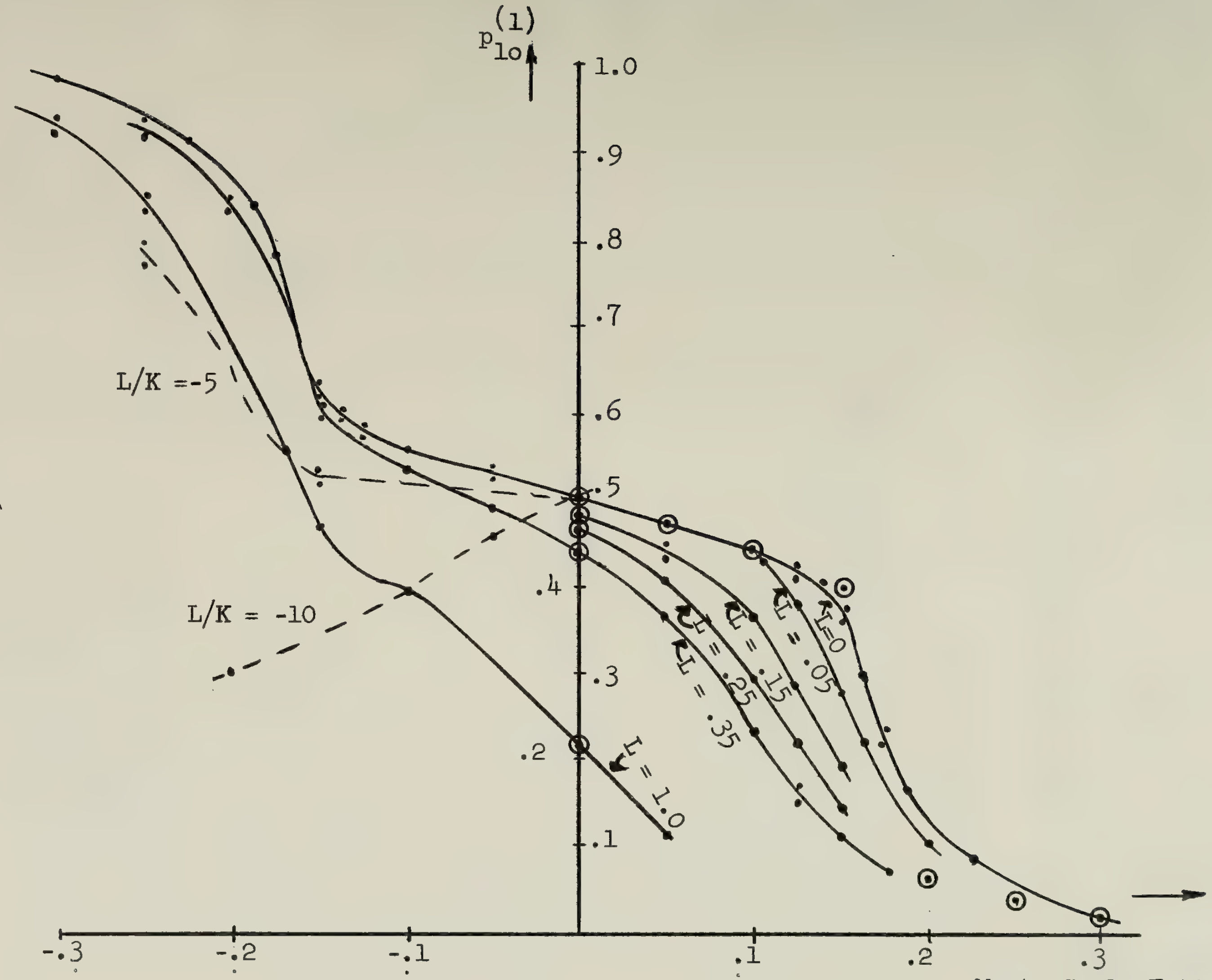

Figure 9: Short-Range Order as a Function of K

. Monte Carlo Estimates

⊙ Calculated by Other Means (Wakefield)

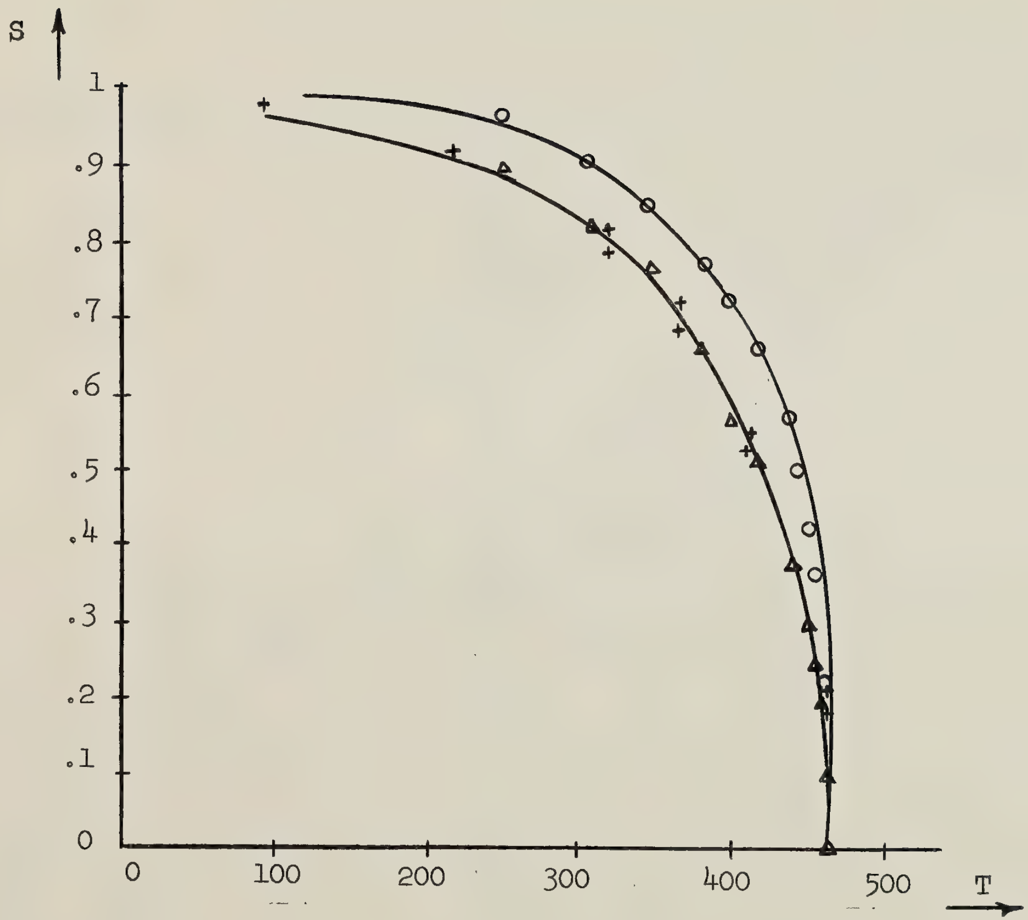

Figure 10: Comparison between Experimental Results and Theoretical Predictions, for Zero External Magnetic Field

o Experimental (Chipman and Warren)
Bethe 2nd Approximation
+ Monte Carlo

PART III

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of May two new routines were added to the Illiac Library.

X14-266 Sexadecimal Punchout and Input Routine - Williams Memory and Drum (SADOI Only). This routine produces a sexadecimal tape of a program stored in either the Williams Memory or on the drum. Its use is recommended for long programs with time consuming input or ones that have been code checked and are ready to go into production.

(W. C. Jacob)

M27-267 Linear Matrix Equation Solver and General Matrix Inversion Using Drum Storage (SADOI Only) (Closed). This routine is a closed subroutine version of the extended matrix equation solver and inverter previously described in M24-260 in its complete program version.

Illiac Usage

During the month of May specifications were presented for 24 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1405 T. Numbers followed by T are for theses.

1405 T Marketing. An Examination of Price-Quantity Relationships. This problem will use multiple correlation to determine the relationship that exists between price, quantity, and income.

1406 Animal Science. Matrix Scaling. Output matrices for least squares problems commonly are produced in such a way that many elements have several zeros after the sign. This program will scale rows and columns by individually chosen powers of ten: that is, the amount of scaling is separately determined for each row and for each column.

1407 T Agricultural Economics. Soybean Meal. An attempt will be made to analyze the factors which affect the price of soybean meal. Once the main factors affecting price have been determined, a forecast of the price for the future year will be made. The Illiac will be used in an effort to find which factors are the best.

1408 T Agronomy. Soil Organic Matter Study. This is a study of different ratios of nitrogen on various amounts of straw to see if soil nitrogen and carbon would change over a long period of time. Changes in nitrogen and carbon will be analyzed using Analysis of Variance.

1409 Agronomy. Corn Stalk Rot. This is a study at different locations of the effect of stalk rot on corn yields. Analysis of Variance will be used to analyze differences in fresh shelled corn weight, dry shelled weight, and weight of 100 kernels.

1410 Mathematics. Solution of the One Dimensional Wave Equation. The wave equation $y_{xx} = y_{tt}$ will be solved by two different methods; one an explicit and the other an implicit method. The explicit method is the usual straightforward finite difference approximation while the implicit may be defined as follows:

set $u = y_x$; $v = y_t$ then $v_t = u_x$ and $u_t = v_x$.

The implicit scheme is

$$\frac{v_j^{n+1} - v_j^n}{\Delta t} = \frac{u_{j+1/2}^{n+1} - u_{j-1/2}^{n+1} + u_{j+1/2}^{n} - u_{j-1/2}^{n}}{2\,\Delta x}$$

$$\frac{u_{j-1/2}^{n+1} - u_{j-1/2}^{n}}{\Delta t} = \frac{(v_j^{n+1} - v_{j-1}^{n+1}) + (v_j^{n} - v_{j-1}^{n})}{2\,\Delta x} .$$

The scheme has the advantage that it is stable for all values of the mesh ratio $\frac{\Delta t}{\Delta x}$. Numerical results for various values of $\frac{\Delta t}{\Delta x}$ will be obtained.

1411 T Sociology. Cross Cultural Study of Selected Values. The problem is concerned with a cross cultural comparison of selected values believed to be the principle elements of normative value systems. The selected values utilized are those theoretically and empirically isolated through research using American college students as the research sample. In this study the values are being subjected to a foreign student sample. The values in question are expressed by 103 statements

(variables). In previous studies with American students these variables factored into four principle factors of significant and substantive meaning. The problem of this thesis is to test the universality of these factors; i.e. to see if the factors again appear when subjected to seven distinct cultural groups.

The mathematical principles involved are those related to the factor analytic technique of analysis. Illiac will be utilized to compute a factor analysis for the entire sample and seven sub-samples (thus eight samples in all).

In order to compare the results of foreign students with American students, a factorization of an American student sample may have to be done -- this decision can't be made at this time.

The problem further specifies that if the first hypothesis is confirmed, i.e. that regardless of cultural influence the four principle components of values systems emerge as factors, then a cross cultural comparison of these four components will be made to ascertain to what degree each of the seven cultures manifest the four component elements. Mathematically this will be done by Illiac through the computation of individual factor scores for the total sample.

1412 Structural Research. Stresses in Layered Media. This investigation is concerned with the determination of the distribution of stresses and displacements in a multiple-layer system occupying half space. Each layer of this system may have different physical properties as well as thickness. However, each layer is considered as a homogeneous medium. The lowermost layer is assumed to extend to infinity.

In the analysis of this system, the expression for stresses and displacements result in the integrals of the type

$$\text{stress or displacement} = \int_0^\infty f(m)\, J_0(m\rho)\, J_1(m\alpha)\, dm$$

for axially symmetrical loadings, or

$$\text{stress or displacement} = \int_0^\infty f(m)\, \cos(m\rho)\, \sin(m\alpha)\, dm$$

for loadings producing plane strain conditions.

In the above integrals J_0 and J_1 are the Bessel functions of first kind and of order zero and one respectively. α and ρ are problem parameters. The function f(m) depends upon the physical properties of the layered system and the conditions at the interfaces between the layers. The boundary conditions give

rise to (4n-2) simultaneous algebraic equations from which (4n-2) constants of integration can be evaluated. n is the number of layers. The constants of integration are, more precisely, functions of m. Thus for each value of m the set of simultaneous equations is solved to obtain the constants, and then f(m) is evaluated for the same value of m.

The integrals are to be evaluated using Gaussian quadrature formulas.

It is desired to extend the programs prepared for axially symmetrical loading to consider the loadings producing plane strain condition.

1413 Chemistry. Molecular Dissociation. An attempt is being made to develop better empirical functions for potential energy surfaces of three body collision problems as evaluated via Hamiltonian functions both in the classical and in the quantum mechanical sense. These functions, based on curvilinear coordinates, are hoped to be more sensitive to parametric adjustments. They will later be used to study actual collision processes by letting the computer evaluate Hamiltonian differential equations of motion under one, two, and finally three dimensional space conditions, with varying masses, initial kinetic and potential energies.

1414 Chemistry. Periodic Deviation from Shottky Line. Periodic deviations from the Shottky line have been observed and measured. A theoretical explanation is found through quantum theory and numerical calculations are desired to substantiate the theory. Primarily, a solution to the Schrödinger equation in the following form is sought:

$$\frac{d^2\psi(r)}{dr^2} + [E - v(r)]\,\psi(r) = 0,$$

where v(r) is assumed, at first, to be of the form:

$$v(r) = \begin{cases} -E_a & \text{for } r \geq r_s \\ \frac{1}{4r} + \frac{\xi}{4r^2} - fr & \text{for } r \geq r_s \,. \end{cases}$$

The boundary conditions are:

1) For $r < r_s$

$$\psi(r) = \frac{A}{\sqrt[4]{E+Ea}} \left\{ e^{i\sqrt{E+Ea}\,r} + \mu\, e^{-i\sqrt{E+Ea}\,r} \right\}$$

2) For sufficiently large r

$$\psi(r) = \frac{C}{\sqrt[4]{E-v(r)}}\, e^{i\int_\alpha^r \sqrt{E-v(r)}\,dr} \,.$$

The transmission and reflection coefficients, $D = \frac{|C|^2}{|A|^2}$, $R = |\mu|^2$ are to be computed and D is to be averaged as follows:

$$\langle D(E_a, f, \xi, 0)\rangle = \frac{\int_{-E_a}^{\infty} D(E_a, f, \xi, E) N(E, E_a, \Theta) dE}{\int_{-E_a}^{\infty} N(E, E_a, \Theta) dE} .$$

Finally, the deviation $\triangle$ which should be periodic in $f^{1/2}$ is to be calculated and plotted, possibly using the data plotter.

$$\triangle(E_a, \xi, \Theta, f) = \ln \frac{\langle D(E_a, f, \xi, \Theta)\rangle}{\langle D(E_a, 0, \xi, \Theta)\rangle} .$$

1415 T Animal Science. Phosphorus Studies with Swine. Measurements were taken of the amount of phosphorus present in the blood of swine. The swine were subjected to treatments and measurements taken at three times during the day every other day for one week. The problem is to find if the treatments had an effect on the level of phosphorus in the blood and if this effect was modified by the time of day or day during the one week experiement. The data will be analyzed by the method of least squares.

1416 T Sociology. Experimental Factors in Exchange. The objective is to study patterns of association between overt and covert attributes of a single area of interaction. (Exchange) This will involve factoring out several sub-areas of belief about Exchange and then attempting to study the relation between factor loadings with distinctive Exchange patterns obtained in a small group laboratory.

All techniques to be used here are in the area of multivariate analysis using available programs.

1417 T Civil Engineering. Analysis of Rectangular Continuous Plate. The analysis is primarily involved with the analytical studies of deflections, moments and shears of rectangular continuous plates with beams of torsional and flexural stiffnesses.

The governing differential equation of a plate is

$$\frac{\partial^4 w}{\partial x^4} + 2 \frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} = \frac{q}{N}$$

in which w = deflection of the middle plane

q = load intensity

N = stiffness of the plate

x, y = rectangular coordinates.

The main problem is the complicated boundary conditions to be satisfied for continuity between panels.

1418 Agricultural Economics. Guide Line of Land Appraisal. This is part of a study of the guide land line of land appraisal and land value changes as influenced by interstate highways and other factors in Illinois. The least square method is used.

1419 T Civil Engineering. Creep Investigations of Symmetrical Shells. The problem to be solved is that of a symmetrically loaded shell, which is assumed to creep at a constant elevated temperature. Applications of this problem may be found in the field of missiles (in particular, nose cones).

The mathematical principles and procedures involved essentially belong to the class of problems generally known as relaxation problems. The shell is divided into a network of beams for which the stress-strain relationships have been established. By the use of a procedure which employs distribution, carry-over, and stiffness factors as in the Hardy Cross moment distribution method, resultant forces in the beams due to assumed radial deflections are adjusted till they are in equilibrium with the applied forces at the node points.

It is the intention to program a procedure by which numerical results for stresses and deflections may be obtained at regular time intervals as the creeping proceeds. This program should be flexile, so that shells subjected to different conditions, such as temperature level, geometry, and material properties may be investigated.

1420 State Water Survey. Calculation of Collection Efficiency. The number of raindrops of each allowable size is available. Approximately 3,000 such number-size distributions are available. It is desired to know the ability of rainfall falling with these number-size distributions to cleanse the atmosphere. The collection efficiencies for each of the drop sizes have been calculated. It is proposed that the Illiac be used to perform the following multiplication and summing:

$$E = \sum_{D=0.5}^{D=8.0} N_D \; K_D$$

where N_D is the number of drops of diameter D; K_D is a constant containing fall velocity, collection efficiency, and area; and E is the scrubbed volume of air per minute.

1421 T Civil Engineering. Determination of the Rayleigh Wave Frequencies for a Two Layered Elastic Half-Space. The frequencies of the generalized Rayleigh waves associated with the dynamics of a two layered elastic half-space are given by the roots of the equation:

$$(\gamma_1^2 - 4m^2\alpha_1\beta_1)(-\delta_{13}+\delta_{24}\, e^{-2(\alpha_1+\beta_1)d}) - 4\gamma_1(\alpha_1\beta_1\delta_{12}+m^2\delta_{34})\, e^{-(\alpha_1+\beta_1)d}$$

$$+(\gamma_1^2 + 4m^2\alpha_1\beta_1)\ (\delta_{23}\, e^{-2\alpha_1 d} - \delta_{14}\, e^{-2\beta_1 d}) = 0$$

where δ_{mn} is the determinant obtained by crossing out the m^{th} and n^{th} columns of the array:

$$\begin{array}{cccccc}
1 & 1 & 1 & 1 & -1 & -1 \\
\alpha_1\beta_1 & -\alpha_1\beta_1 & m^2 & -m^2 & -\alpha_2\beta_1 & -m^2\beta_1/\beta_2 \\
\gamma_1 & \gamma_1 & 2m^2 & 2m^2 & -\frac{\mu_2}{\mu_1}\gamma_2 & -2\frac{\mu_2}{\mu_1}m^2 \\
2\alpha_1\beta_1 & -2\alpha_1\beta_1 & \gamma_1 & -\gamma_1 & -2\frac{\mu_2}{\mu_1}\alpha_2\beta_1 & -\frac{\mu_2}{\mu_1}\gamma_2\beta_1/\beta_2
\end{array}$$

The symbols used are defined as follows:

$$\alpha_n = m^2 - \frac{\rho_n p^2}{\lambda_n + 2\mu_n}$$

$$\beta_n = m^2 - \frac{\rho_n p^2}{\mu_n}$$

$$\gamma_n = 2m^2 - \frac{\rho_n p^2}{\mu_n}$$

λ_n, μ_n, and ρ_n define the properties of the two media, d is the depth of the upper layer and m and p are independent variables.

The roots are to be found using inverse interpolation. It is known from other considerations that the number of real roots is finite for m and p finite and that these roots must lie in a finite interval.

1422 T Agricultural Economics. Linear Programing Maximization. This problem is a study of the changes in the divergence from economic equilibrium positions of eight groups of farms in the years 1951 and 1957. The Illiac will be used with a linear programing routine to maximize the income level for the groups of farms in these two years subject to the restraints due to the fixed resources. These linear programing estimates will be used in determining the optimal organization of the farms and the income level will be one of the estimates used to determine the economic equilibrium level.

1423 Structural Research. Natural Frequencies of a Simply Supported Cylindrical Shell. This program will use M22 and/or M23 to solve for the natural frequencies and the eigenvectors for a simply supported cylindrical shell. The equations of equilibrium are satisfied using a Fourier expansion in the longitudinal direction and a finite difference grid in the tranverse direction. The coefficients for the stiffness matrix are computed and planted as required for M22 or M23.

The results of this program will be used in the model analysis of the dynamic response of a simply supported cylindrical shell subjected to a blast loading.

1424 T University of Ottawa. Identification of Factors Measured in a College Entrance Test Battery. The problem is twofold:

(1) Validation of Dr. Paul Lilly's Forced-choice Rating Scale. This is a scale devised to measure factors presumably not measured by aptitude and achievement tests frequently used as a college admission battery. The preliminary validation, item analysis, and final validation of the revised scale have been done.

(2) What factors are measured by Lilly's scale and are these factors different from those measured by a college entrance battery (v.g. <u>Ohio State Phychological Test</u> and the <u>Iowa High School Content Examination</u>)?

To answer these questions multiple factor analysis is necessary and the Illiac may be very profitably used.

The steps:

(a) Pearson Intercorrelations

(b) Factor extraction by the centroid method

(c) Factor rotation - varimax method.

1425 Physics. Energy Levels of Nitrogen. The Illiac will be used to compute the magnetic field dependence of the ground state energy levels of atomic N^{14} and N^{15}.

This involves diagonalizing two 3 x 3 matrices for 16 different values of the magnetic field.

1426 Physics. Vacancy Quenching and Annealing. The equations to be solved in Illiac are:

$$(1) \qquad \frac{dz}{dp} = Be^{-\frac{1}{p}} \left[Cz^2 + (z-1)\, e^{\frac{\alpha-1}{p}} \right]$$

and

$$(2) \qquad \frac{dp}{dp} = 1 \, .$$

(B,C constants) having the initial condition: $p = p_i$: $z = z^0$. z^0 is obtained from the condition $\frac{dz}{dp} = 0$ in (1). (1) will be solved for different initial values of p using the Runge Kutta integration procedure. $(\alpha-1)$ is also a parameter. We have to print the solution not as (z,p) pairs but as (c,t) pairs which are related to (z,p) according to the following relations: $c = Nz$, $p = \frac{E}{k}(T_0-\beta t)$; here $\frac{E}{k}$ and β are constants. N, T_0 are also parameters placed on the data tape.

1427 Animal Science. Lamb Weight as Related to Age. Data from the University purebred flocks are being analyzed to ascertain the relation of weight to age, separately for each of four breeds classified into two sexes classified into singles, on the one hand, or twins classified according to sex of cotwin, on the other. This is a least squares problem, to find the best line representing weight as a function of age.

1428 Chemistry. Total Potential Energy of the System H_2 + H. Calculate and print the total potential energy of the system of H_2 and H, holding two of the internuclear distances fixed and varying the third with θ, the interior angle. The equation for the potential energy is modified by λ, the ratio of Coulombic to total energy.

Plot E (potential energy) versus θ (the interior angle of the system).

Table I shows the distribution of Illiac machine time for the month of May.

TABLE I

	Hrs:Min	
Regular Maintenance	43:35	
Unscheduled Maintenance	33:43	
Drum Engineering	32:22	
Leapfrog	29:41	
R.A.R.	6:06	
Library Development	6:52	
Wasted	:00	
		152:19

<u>Use by Departments</u>

Computer	23:13	
Classes	19:48	
Physics	25:28	
Control Systems Laboratory	46:52	
Structural Research	70:51	
Structural Research (AF 464)	3:37	
Structural Research (A.A.S.H.O. Road Test)	5:52	
Psychology (M.H.7289)	:45	
Psychology (P.H.1774)	:29	
Psychology (AF 49 (638) 371)	8:50	
Psychology (ONR 1834(11))	3:47	
Psychology	12:32	
State Department of Public Welfare (1715)	:13	
Sociology	17:39	
Inst. of Com. Res. (9067C)	3:11	
Education	:55	
Bureau of Educational Research	7:46	
Bureau of Educational Research (12-20-60-482)	:26	
Economics	:18	
Economics (NSF 7056)	7:35	
State Water Survey	:58	
State Water Survey (SC 75055)	1:48	
Theor. and Appl. Mechanics (ORD 593 IC)	:22	
Mech. Eng. (ORD 1980)	:17	
Mechanical Engineering	:34	
Min. and Met. Eng. (AF 3789)	:18	
Physics (NONR 1834(12))	:06	
Astronomy (NONR 1834 (22))	:17	
Electrical Engineering (NSFG 7421)	:05	
Electrical Engineering (AF 6079)	4:35	
Electrical Engineering (NSFY 32.40/266)	15:31	
Electrical Engineering	7:25	
Chemistry	103:53	
Agriculture	15:11	
Sydney University, Sydney, Australia	:34	
Demonstrations	3:20	
Miscellaneous	11:59	
		427:20
		579:39

Error Frequency and Analysis

The Illiac is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive, for an error standpoint, to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared, using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:30 - 6:30 period (when the machine is checked), if no errors are found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for May.

TABLE III

Williams Memory	6
Arithmetic	3
Control	8
Reader	3
Punch	5
Drum	26
Power Plant	2
Unknown	5
Total	58

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/1/59	22:00	:00	2:00	0		:00	:40	0
5/4/59	15:24	5:35	3:01	3	(1) and (2) Memory errors 2^{-9} (3) Arithmetic error	:00	1:29	1
5/5/59	20:01	1:07	2:52	3	(1) Arithmetic error (2) and (3) Drum failures	:00	:40	0
5/6/59	16:39	4:47	2:34	2	(1) Arithmetic error (2) Control error	:00	1:06	1
5/7/59	16:22	5:02	2:36	4	(1) and (2) Drum failures (3) and (4) Control errors	:00	:20	0
5/8/59	17:21	4:39	2:00	1	(1) Control error	:00	1:20	0
5/11/59	20:57	:12	2:51	2	(1) Reader "H" error (2) Unknown	:00	1:01	0
5/12/59	20:25	:37	2:58	1	(1) Drum error	:00	:42	0
5/13/59	21:15	:00	2:45	0		:00	:40	0
5/14/59	19:29	1:31	3:00	3	(1) Drum error (2) Memory error 2^{-6} (3) Control	:00	1:17	1
5/15/59	18:56	2:07	2:57	2	(1) Drum error (2) Reader "B" error	:00	:40	0
5/18/59	20:09	:59	2:52	3	(1) and (2) Drum errors (3) Punch 1 error	:00	1:20	0
5/19/59	20:22	:48	2:50	3	(1) Punch 4 error (2) Punch 4 error (3) Drum error	:00	1:00	0
5/20/59	18:53	2:07	3:00	6	(1),(2),(3),(4),(5) Drum failure (6) Punch 4 error	:00	:40	0

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING RAPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
5/21/59	18:16	2:48	2:56	6	(1) Memory error (2) Punch 4 error (3) Drum error (4),(5),(6) Unknown	:00	:45	0
5/22/59	21:41	:19	2:00	5	(1),(2) Memory error 2^{-10} (3) Reader error "K" (4) Drum error (5) Unknown	:00	:57	0
5/25/59	19:29	1:30	3:01	4	(1),(2),(3) Drum error (4) Power Plant failure	:00	:37	0
5/26/59	19:40	1:18	3:02	4	(1),(2),(3) Drum error (4) White switch error	:00	:20	0
5/27/59	20:58	:01	3:01	1	(1) White switch error	:00	:40	0
5/28/59	20:31	1:29	2:00	5	(1) White switch error (2),(3),(4) Drum error (5) Power Plant failure	:00	1:38	0
TOTALS	388:48	36:56	54:16	58		:00	17:52	3

PART IV

IBM 650 USE AND OPERATION

New 650 Codes

During the month of May eight new programs were added to the Digital Computer Laboratory IBM 650 Library.

M1'-23' Floating Point Matrix Inversion and Solution of Simultaneous Linear Equations. This closed subroutine will solve the general matrix equation or invert matrices expressed in floating point form. If n is the order of the matrix and b is the number of sets of linear equations to be solved then the capacity of the routine is bounded by $(n + 1)(n + b) \leq 1923$.

(M. T. Gray)

Y1'-24' Multiple Program Tape Dump and Loader. This is a set of five routines which enable the user to place programs on a tape, dump programs from that tape, insert or add programs to the tape or edit the tape.

(R. H. Flenner)

Y2'-25' Tape Duplication. This program will duplicate either an alphabetic or a numeric tape.

(K. E. Shannon)

Y3'-26' Tape of Variable, Known Record Length to Printer/Punch. This program will read either an alphabetic or numeric tape of variable but known record length and either print it or punch it on cards.

(K. E. Shannon)

Y4'-27' Tape of Fixed Record Length to Printer or Punch. This program will read either an alphabetic or numeric tape of fixed record length and either print it or punch it on cards.

(K. E. Shannon)

D2'-28' <u>On Line Tracing Routine of Drum, Core, and Tape Instructions.</u> This routine is similar to D1'-16' except that it is capable of tracing all possible IBM 650 orders.

(M. T. Gray)

X6'-29' <u>High Speed Drum Clear.</u> This routine uses index registers and fast storage in order to clear the drum as rapidly as possible. Only three card cycles (about .02 seconds) are required.

(R. H. Flenner)

T4'-30' <u>Fixed Point Arctangent Subroutine; Entry Symbol TXXX4.</u> This routine will compute the arctangent of an argument in fixed point form.

(R. H. Flenner)

<u>IBM 650 Usage</u>

During the month of May program specifications for the 650 are:

10' Statistical Services Unit and Student Counseling. Freshman Guidance Examination Scoring. The 650 will be used to score the battery of Freshman Guidance Examinations which are administered to all entering freshmen. The battery consists of approximately eight different tests. Most of the tests have unitary weighted items and scores are computed as a function of the number of right answers as well as the number of wrong answers given. The Kuder Vocational Preference Record has weighted items and is scored on some 40 odd scales.

All the raw scores are converted to meaningful deciles to aid in reporting test results and counseling the student. At present, about 4,000 students are tested each year. The required 650 usage is expected to coincide with the following testing periods:

a) February 12% of the students
b) April 5% of the students
c) May 20% of the students
d) June 18% of the students
e) July 10% of the students
f) September 35% of the students.

11' Statistical Services Unit and Dairy Science. Dairy Herd Improvement Association. Many of the dairy herds throughout the State of Illinois are enrolled in the DHIA program, which is now offering centralized calculation of records to its members. The number of farmers requesting the type of service is on a steady increase. Volume is now at approximately 20,000 animals and is expected to increase to 50,000 animals in less than two years.

Members of the DHIA program are visited once each month by a DHIA supervisor. The supervisor gathers data including dates on which cows freshened, went dry, etc.; daily milk and grain weights and butterfat percentage measured for each cow; and the current local prices of milk, grain, roughage, etc.

The 650 will be used to extend these daily figures to monthly totals for each cow and to accumulate these figures to lactation and lifetime totals for each cow and to monthly and annual herd totals and averages. This involves the maintaining of a tape file and the preparing of several reports from that file. These reports include:

1. Monthly Individual Cow Report - Run weekly to distribute the work load showing milk, fat, grain, grain cost, income over feed cost, etc. for each cow for the current month and for lactation to date. It also shows herd averages for the month and a revolving 12 month herd average.
2. 305 - Day Lactation Certificates - Run monthly. Showing totals of milk, fat, grain, etc. for the first 305 days of each lactation and totals of lifetime production for each cow.
3. USDA 305 Day Lactation Card. The above figures punched in cards to be sent to USDA ARS to be used in sire proving.
4. County Report - Run monthly. Showing all herd totals and averages for current month as well as county totals and averages.
5. Annual Report. Same as County Report but showing annual totals.

In addition to these reports, useful data will be made available for use by Dairy Science and the Department of Agriculture for study of feeds, production and conditions affecting these records. Various other statistics will also become more accessible.

12' Civil Engineering. Influence Lines for 2-Hinged Arch. The problem is to develop a program which will compute the influence line ordnates for the horizontal reactions of a second-degree parabolic two-hinged arch with constant moment of inertia.

The computer will determine the geometric properties of the arch, the deflections of the arch, and finally the influence line ordnates.

The mathematical operations involve only the computation of the area of a triangle and a parabala, and the length of the hypotenuse of a right triangle. The library square root subroutine will be used.

13' T Agronomy. Management of Stocks. This is a study of various factors influencing the growing of stock flowers. The 650 will be used to compute variances within groups and an analysis of variance.

14' Home Economics and Statistical Services Unit. Survey of Laundry Procedure. The 650 is to be used on a questionnaire analysis to determine factors determining laundry practices. The questionnaire contains 140 items and was administered to a sample of 600 households in Illinois. Cross-classification frequency tables and percent cases in each category will be computed for all pairs of items. Further computing, such as a chi square, may be done on the frequency tables in the cases where interpretation of the results is indeterminant.

15' Civil Engineering. Automatic Analysis of Continuous Trusses. This program is essentially an extension of Illiac Program 1163T. It is an attempt to formulate a set of rules by which a complete engineering design process can be carried out on the computer. The original program, when given a fixed configuration of the system, the external constraints (loading) and internal restrictions (allowable stresses and limiting minimum areas), produced a unique solution satisfying all the imposed criteria. This is accomplished through an iterative solution of the equations of elasticity governing the system.

The proposed program will extend the basic program to include:

1. A variation of the configuration to optimize the design with respect to a given set of parameters.
2. To determine whether extreme variations in the configuration may produce instability of the solution, and to formulate a set of rules governing such cases.

16' Statistical Services Unit. Program Testing - Administrative. Investigation and development of computer methods for testing subroutines for use on problems of a business data processing nature. The investigation to involve techniques of

an accounting and statistical nature involving such areas as the Business Office and D.H.I.A. Techniques include sorting and classification of data, summarizing, tabulating, frequency distribution, decision analysis, etc.

Table I' shows the distribution of the IBM 650 machine time for the month of May.

TABLE I'

	Hrs:Min		
Regular Maintenance	8:27		
Unscheduled Maintenance	3:35		
Library Development	30:38		
Wasted*	115:19		
		157:59	
Use by Departments			
Statistical Service Unit	6:56		
Structural Research	2:49		
Theor. and Applied Mechanics	:10		
Classes	20:22		
Agronomy	:03		
		30:20	
			188:19

Error Frequency and Analysis

The IBM 650 is normally on from 8 a.m. to 5 p.m. The machine is used for preventive maintenance from 8 a.m. to 12 noon on Wednesdays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance. It should be noted that the excessive wastage during the month of May was occasioned by the necessity of turning the machine off for approximately two hours after each one-hour running period to permit it to cool.

Table III' presents a summary of errors for May.

TABLE III'

Error due to power supply having a bent connector	1
727	5
533	3
Total	9

* This excessive wastage was occasioned by enforced cooling periods due to the lack of air conditioning.

TABLE II

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED*	FAILURES STOPPING OK TIME	TYPES OF FAILURES CAUSING REPAIR TIME
5/1/59	1:21	:00	:00	7:39	0	
5/4/59	:43	:00	:00	8:17	0	
5/5/59	:00	:00	:00	9:00	0	
5/6/59	:00	:00	:00	9:00	0	
5/7/59	:10	:17	:00	8:33	0	
5/8/59	:48	:00	:00	8:12	1	(1) Bent connectors in the power supply
5/11/59	:52	:00	:00	8:08	0	
5/12/59	:00	:00	:00	9:00	0	
5/13/59	:59	:00	:00	8:01	0	
5/14/59	1:08	:00	:00	7:52	0	
5/15/59	1:10	:00	:00	7:50	0	
5/18/59	:27	:00	:00	8:33	0	
5/19/59	4:37	:00	:30	3:53	2	(1) Tape unit error (2) Tape unit error
5/20/59	2:55	4:00	:00	2:05	0	
5/21/59	5:33	:00	:33	2:54	2	(1) Tape unit error (2) Tape unit error
5/22/59	5:57	:00	2:04	1:14	1	(1) Tape unit error
5/25/59	6:24	:00	:00	2:36	0	
5/26/59	5:31	4:10	:00	1:04	0	
5/27/59	9:25	:00	:00	:00	0	
5/28/59	7:07	:00	:28	1:25	3	(1),(2),(3) 533 not reading last card of Soap correctly
5/29/59	5:51	:00	:00	:03	0	
TOTALS	61:58	8:27	3:35	115:19	9	

* This excessive wastage was occasioned by enforced cooling periods due to lack of air conditioning.

PART V

GENERAL LABORATORY INFORMATION

Reports and Seminars

Report

Report No. 88, "The Decision and Synthesis Problems in Semi-Modular Switching Theory," by James H. Shelly, May 20, 1959.

Seminars

"Shiftrix Arithmetic", by Prof. Gerald Estrin, University of California, Berkeley, California, May 4, 1959.

"Statistical Library for Illiac and IBM 650, Past, Present, and Future", by Kern W. Dickman and Samuel J. Penny, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, May 11, 1959.

"Temperature Effects in Transistors and Diodes", by Prof. T. A. Murrell, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, May 18, 1959.

"Some Considerations in the Design of an Arithmetic Unit", by Dr. David J. Wheeler, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, May 25, 1959.

Personnel

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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - MATHEMATICAL METHODS

PART III - ILLIAC USE AND OPERATION

PART IV - IBM 650 USE AND OPERATION

PART V - GENERAL LABORATORY INFORMATION

June, 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The Rich Electronic Computer Center at Georgia Institute of Technology is participating in this work by the support of a staff member at the University of Illinois.

1. Basic Circuits

As a continuation of the study completed in May, the transient behavior of transistors at high injection levels was investigated and basic experiments were done. The results may be summarized as follows:

(1) The alpha cutoff frequency at a high injection level is slightly greater than twice that at a low injection level.

(2) The change-over point from low injection level to high injection level lies under 6 or 8 ma for the GF-45011 transistor tested. There was no increase in the cutoff frequency observed beyond this range.

(3) The results obtained in (1) and (2) closely agree with the calculated values based on the existing theory of junction transistors. However, the collector capacity dependence upon the collector voltage revealed an interesting departure from the theories; it deceases more rapidly than predicted by the theories. This may be due to the field localization effect on the collector junction and to the temperature effect caused by the high collector dissipation.

Utilizing these results, it may be possible to construct AND, OR circuits whose gain is a little greater than unity and whose time constant is sufficiently small so that there is no need for level restorers.

(T. Kunihiro)

Matrix Circuits. A design error in the general matrix circuit was discovered and corrected. As a consequence, the rules for assembly of matrix circuits have been modified and, by removing the restriction on input voltages, also slightly simplified. However, the circuit has non-standard input currents (1,7 ma. instead of the standard 1.2 ma.). Experiments are in progress to estimate the speed of the redesigned circuits.

Diode and Transistor Characteristics. The latest measurements on diode S577G forward characteristics and GF45011 V_{EB} forward characteristics were plotted and duplicated. Both opaque and transparent copies are available to facilitate graphical analyses of circuits using these components.

Analogue Predictor. Some preliminary work was done on the design of a 7-bit analogue predictor for use in the base-4 division selection process. Although at an early stage, it is felt that 7-bits will prove outside the precision available from an analogue circuit of this kind, and that 5-bits is a probable maximum.

(N. E. Wiseman)

The design of an asymmetric flipflop with a reply signal was investigated. The reply signal appears only after the input signal is present, the gate signal is present, and the output signal is also present.

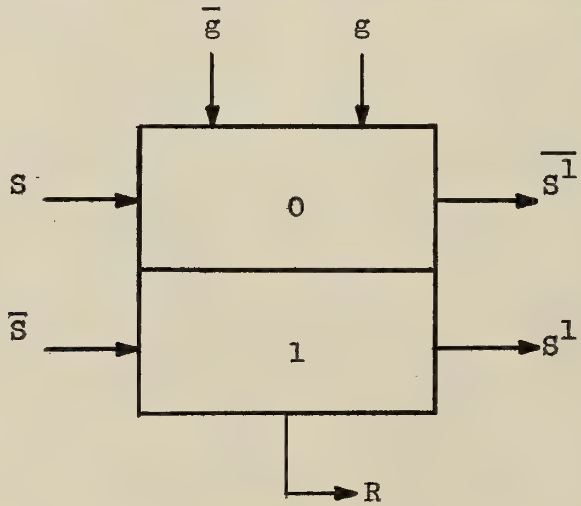

Figure 1

The previously designed Schmidt-trigger flipflop (Figure 1) with reply signal required S, $\overline{S}$, g, $\overline{g}$ and a circuit using 14 transistors and 23 diodes. The reply has the Boolean form $R = g \cdot (S\,S^1 \text{ v } \overline{S}\,\overline{S^1})$. Since this was quite expensive, another type was desired. A new one (Figure 2) was designed which requires g, S, and a circuit of 10 transistors and 29 diodes. It is essentially a new type of F-element in which the logic (including the Reply logic) is built into the collectors of the F-element. The circuit is now being built for testing.

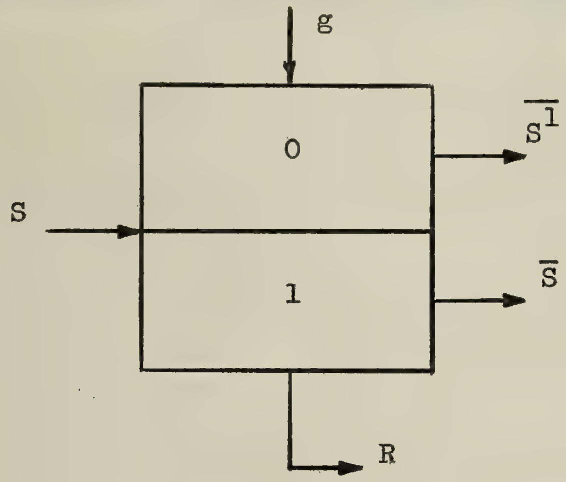

Figure 2

(N. Johnson)

2. Core Storage Unit

During this month, some experimental tests of disturbance effects on the memory were performed. The test was composed of the full selection of a given word, W_1, a number, n_1, of consecutive times while half-selecting the switch core of another word, W_2, after which W_2 is fully-selected once to observe the creep of its bit cores. The number of disturbs, n_1, has thus far been varied only from 1 to 7 with the result that the read-out signal from W_2 decreased by about 5 per cent when n_1 varied from 1 to 7. This test was done with switches at room temperature.

Another problem, whose solution has not yet been found, was studied. The effect is as follows: When the digit drivers are turned on each acts on the 4094 bit cores of 2047 unselected words by forcing them to move some small

amount along a reversible flux path. The amount, ΔB, by which the affected bit core's flux density changes, is strongly damped by the very low resistance word (W) lines which link all words. Nevertheless, when the digit drivers turn off, all bit cores, through which the digit line threads, fall back toward $H = 0$, producing about 1 mv. each (initially) and decreasing with a time constant, L_w/R_w where

L_w = effective inductance of a word line

R_w = total resistance of a word line.

The net effect is for a difference voltage, to develop across the sense

$$V_D \cong 4 \exp\left[-\frac{R_w}{L_w} t\right] \underline{\text{volts}} \qquad (t = 0 \text{ at digit driver turnoff } L_w/R_w \cong 0.2\ \mu s.)$$

amplifier input which must be allowed about 1 µs to dissipate to the point that the next memory cycle can be started. This extends the total cycle to about 2.1 µs. The measurements, made in this connection, were performed on a model which is quite different, in some important respects, from the actual memory, and should not be considered final.

(S. R. Ray)

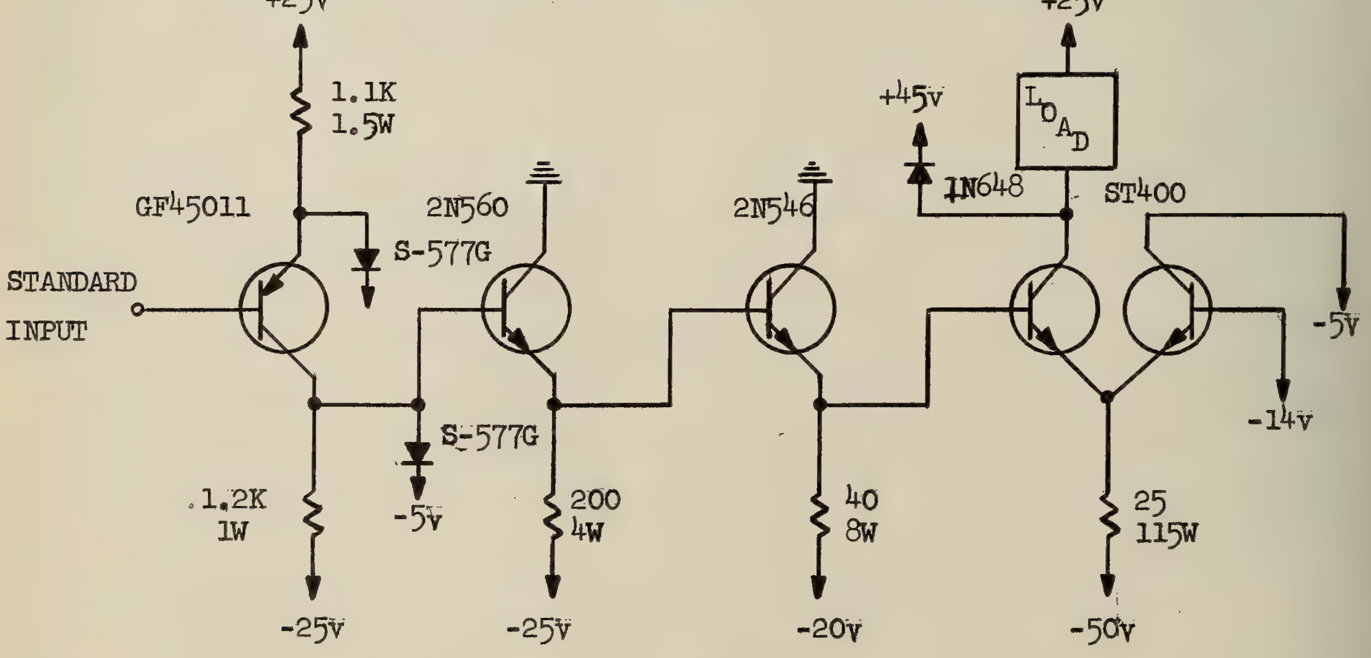

Figure 3

The driver of Figure 3 was built and tested. Its capabilities are 1.5 amp at 30 volts across the load. From the time the turn on pulse is 10 per cent down, the total delay and fall time is 220 mμs. From the time the turn off pulse is 10 per cent up, the total delay and rise time is 300 mμs. The times were measured on the unit which was built, and changing the GF45011, the 2N560 and the 2N546 for second units of the same type did not change the times any measurable amount. From the waveforms observed, most of the time in the circuit is in the ST 400 transistors.

(J. L. Muerle)

A variable memory timer (1 to 1.5 μsec) has been constructed, and tests of reliability and pulse length variation are proceeding.

The design of variable voltage regulators (2 to 20 volts at 2 amps output current) to operate from 25 volt supplies has been undertaken.

(J. D. Leslie)

3. Arithmetic Unit

Investigation of the division process described in Report 82 revealed:

(a) A quotient digit predictor was found to cost roughly 300 transistors; two such predictors would be required to utilize the ability to add on both up and down shifts.

(b) Other than equipment, this implementation costs, in time, at least three collector delays per add operation more than the maximum gating rate possible.

The final selection between this quaternary scheme and simpler binary technique will be postponed until data on the delay and precision of an analogue assimilator and comparator is available.

A final selection of data paths in the arithmetic unit has been made. The primary differences between the layout and that shown in the April Report as design 4 are:

(a) Insertion of shift gates at the accumulator adder output rather than the adder inputs.

(b) Elimination of one of the memory operand registers shown in design 4.

(c) Use of low level rather than high level selectors.

(d) Assimilation employs a fast carry generator. Using the notation of Report 80, the carries are generated from the contents of A and C in such a way that they may be added, using a pseudo-adder, to the contents of A and C to yield the assimilated result in $\overline{A}$. Selection of the carry generator rather than M is required.

A detailed description of this layout is being prepared as a file number.

(R. Shively, D. J. Wheeler)

4. Auxiliary Storage

Results of tests on two types of stabistors, Transitron S-320G and SG-22 were summarized in File No. 283. These devices are to be used for generating nonstandard reference voltages in test equipment.

Gate drivers and input circuit were designed for the 16-stage ring counter, and construction of this unit is in progress.

(R. L. Cummins)

The design of a peak-sensing read circuit for the magnetic tape unit has been completed. A bread-board setup of the circuit was tested and its performance was found satisfactory for sinusoidally simulated read-back voltages over a range from 5 mv peak-to-peak to 25 mv peak-to-peak, and up to a frequency of 150 kc. This frequency corresponds to a packing density of about 1500 bits per inch at a tape speed of 200 inches per second.

(C. N. Liu)

The clock pulse generator was modified, so that the useful frequency range now extends from 800 cycles/sec to over 400 kc. A start circuit has been designed for the clock pulse generator, for use with other test equipment.

Work is presently in progress on the design of the output circuit for the programmed pulse train generator.

(L. J. Peek)

5. Tolerance Analysis

The SIR KITTSOLVER program has now been checked on a variety of circuits, the most complicated of which was a J element. Each circuit was also run with the tolerance analysis program (1206). Minor discrepancies in the two sets of results or the order of 0.4 ma in branch currents, were accounted for by slight differences in the diode and transistor tables. In one test 1206 stopped on a solution corresponding to unstable equilibrium while SIR KITTSOLVER found the correct solution. It took seventy seconds for SIR KITTSOLVER to obtain the solution for the J element including time to read the data tape and print the solution. A complete set of directions for using this program is now being prepared.

(L. D. Fosdick)

6. General Organization

Further consideration of the order code has suggested that 13 bits are insufficient or make it very difficult to encode "in a reasonable manner" the range of orders desired. Working on a basis of a 52 bit word structure, we may next try three orders per word of 14 through 17 bits each. The following proposal was 16 bits per order, for which an order code has been devised. The first 8 bits are the function digits, the next two indicate the meaning of the address digits, long or short order, etc., and the last 6 form an address of a word in temporary storage. To be consistent, address and index registers are also 16 bits in length. The remaining four bits of an order triplet and the three extra bits in the address are not wasted, but indicate buffer storage orders and operands respectively, enabling a saving in control complexity. It is also claimed that it is easier to program automatic allocation of temporary storage.

The proposal calls for twelve 52 bit flow gating registers or their equivalent. These may be thought of in two groups, T_0, - T_3, and I_0 - I_7.

The T_i may be used for temporary storage, index register (3 per word) and buffer storage of "from memory" operands.

Two bits of each 16 bit address of an operand indicate which of the four buffers is to be used.

The I_i may be used for temporary storage index register and buffer storage for the program. After completing an order triplet each control unit can examine three of the remaining four bits to determine which of the I_i holds or will hold the next operation triplet. Thus program loops of up to 24 words may be held in temporary storage, or at the other extreme we may use 33 index register or 11 temporary storage locations. In this sense the system is flexible. It appears to be relatively easy for the input routine to allocate the temporary storage locations efficiently.

An additional feature is that "short" numbers of 16 bits are allowed. The addressing of temporary storage is such that 0, 4, 8,...,44 refer to the full registers $I_0, \ldots, I_7, T_0, \ldots, T_3$. The other addresses refer to "short" numbers, index registers or order depending on the order. Thus address 10 would be the second 16 bit group of I_2.

(C. W. Gear)

PART II

MATHEMATICAL METHODS

1. Continued Fraction Expansions for the Ratios of Hypergeometric Functions
(Supported in part by the Office of Naval Research under Contract Nonr-1834 (27).)

Continued fraction expansions of the type

$$b_o + c_o z + \frac{a_1(z - z^2)}{b_1 + c_1 z} + \frac{a_2(z - z^2)}{b_2 + c_2 z} + \ldots$$

for the ratios of continguous Gauss functions are discussed in detail. Such expansions converge to the generating ratio if $R(z) < 1/2$, and to a different ratio if $R(z) > 1/2$. Recurrence formulas for the numerators and denominators of the approximants of related continued fractions are derived.

PART III

ILLIAC USE AND OPERATION

Illiac Usage

During the month of June specifications were presented for 24 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1429. Numbers followed by T are for theses.

1429 Theoretical and Applied Mechanics. Axisymmetrical Shells. The problem is to determine the stresses in various axisymmetric configurations due to a symmetrical load, by integrating the corresponding differential equations of equilibrium and deformation.

1430 T Electrical Engineering. Delta-E. This routine uses drum data from Routine 1153 T to compute the mismatch in the boundary condition. The equation solved is:

$$1 + \Delta E = \int_0^{\ell} I_{11}(x) \quad H_0^{(2)}(|x-a|)dx$$

where a is a parameter. The Hankel function is being computed presently by the integral representation:

$$H_0^{(2)}(y) = \frac{2}{\underline{\underline{u}}}\int_1^{\infty} \frac{\sin xt + j \cos xt}{t^2 - 1} dt \quad ,$$

but other methods will be tried later.

1431 Psychology. A Factor Analysis of Personality Questionnaire Items. Ninety-two questionnaire items were given to 3,600 men in service and were scored and intercorrelated. The specific problem is to find a minimum rank of the correlation matrix that will allow reproduction of these correlations. Once this has been determined, the problem becomes one of rotating obliquely the r axis that represent the matrix rank into the more parsimonious position in the r-space. This will involve the Ohlimax program and visual 35mm. plots that will be rotated by hand. Once a parsimonious solution has been reached, it would be desirable to find the r simultaneous linear equations that would allow the prediction of scores on a criterion for future work in the area. The procedure followed throughout the problem is essentially that used by Cattell, Peterson and others in the Psychology Department.

1432 T Agronomy. Semen Liveability. This thesis is a study of the effect of temperature, CO_2 level, sodium bicarbonate, and dilutens on the storage life of bovine semen. Motility, pH, and rate of movement are data to be analyzed by Analysis of Variance.

1433 T Geology. Hydrometer Analysis of Sediment. In this investigation core samples from Lake Michigan are being studied. The character of these samples will be studied to determine the textural and mineralogical properties of the material in order to obtain a more complete interpretation of the glacial-geologic history of Lake Michigan. The grain size analysis of silt and clay fractions of the lake material is one of the methods used to obtain this information, because it is an aid in the determination of changing lake conditions and the type of source material.

To give a complete picture of this distribution the grain size distribution of 200 core samples is being determined. The grain size distribution of the silt and clay portion of each sample is determined by hydrometer analysis which is briefly described below.

Each core sample is mixed with water, thoroughly shaken in a sedimentation cylinder, and allowed to settle. The density of the suspension is determined periodically with a soil hydrometer. Certain simple formulas based on Stoke's Law convert the density information to the percentage of soil smaller than a certain diameter. The density of the suspension changes with time since the larger particles settle faster than the smaller ones. A series of readings at various times gives the size distribution of the sample.

With the basic data: weight of sample, elapsed time, hydrometer reading, and the temperature of the suspension at the time of the reading, the digital computer can select values of D, K, and L, and solve the equations.

1434 Physics. V_K Integrals. The integrals are required for the calculation of the electronic contribution to the binding energy of the V_K center in LiF, the model essentially being a hole trapped by two adjacent ions. The integrals required are of the general form:

$$\int \psi_A \nabla_A^2 \psi_A \, dc, \quad \int \psi_A \nabla_A^2 \psi_B \, dc, \quad \int \psi_A V(r_A) \psi_A dc, \quad \int \psi_B V(r_A) \psi_B dc \text{ and } \int \psi_B V(r_A) \psi_A dc$$

where ψ_A and ψ_B are atomic orbitals centered around A and B and $V(r_A)$ is a spherically symmetric potential centered at A. The two center integrals are being computed using Lowdins α-junction technique (Phil. Mag. Suppl. 5, No. 17, pg. 1 (1956)).

1435 Electrical Engineering. Calculation of the Position of Sun. The position of the sun in terms of azimuth and declination is calculated from known trigonometric formulae. The Greenwich Hour Angle and the declination of the sun, obtained from from the Air Almanac, are fed into the calculator along with the day and time at which the position of the sun is to be calculated. The output contains the day, time, the azimuth (in degrees) and declination (in degrees).

1436 Water Survey. Correlation of Water Quality with Corrosion Rate. Sample pieces of cast iron metal have been exposed to solutions containing variable concentrations of corrosion and protective chemicals. Frequent observations of the amount of corrosive deposits on the metal were made. A final rate of corrosion deposit was approached after a period of exposure.

The use of K-14 can help in a correlation and regression analysis and the development of an emperical expression for the corrosion rate as a function of water quality.

1437 T Electrical Engineering. A-C Servo Motor Analysis. This problem requires the solution of a set of four nonlinear first order differential equations using the F1 routine. A total of ten different quantities will be computed as functions of time.

The equations describe the behavior of an a-c servo motor with suppressed carrier modulated control excitation. The objects of the problem are five-fold.

1. Determine a transfer function for the motor.
2. Determine instantaneous speed and torque curves.
3. Determine Thevenin's mechanical equivalent at output shaft.
4. Determine average-to-peak torque ratios.
5. Effect of saturation on performance--namely, roll-off of corner frequency at higher levels of excitation.

1438 T Physics. Paramagnetic Resonance of the M-Center. The paramagnetic resonance spectrum of an additively-colored KCl crystal in a gaussian line centered at g = 1.995 and about 50 gauss wide. Under this resonance is hidden the M-center resonance, probably also gaussian, with slightly different parameters. These combined spectra probably could not be satisfactorily resolved per se. By inverting the populations by adiabatic fast passage, then observing the spectrum after the centers have decayed towards equilibrium with their characteristic time constants,

a sequence of spectra is obtained in which the components have varying relative amplitudes. A least squares fit to these spectra is necessary to determine the parameters of the individual components.

A program written by F. Blankenship will probably be used to fit gaussians to the data by minimizing X^2. It is hoped that the parameters of the gaussians (except the amplitudes) will remain roughly constant. If so, it may save machine time to minimize only once and then set up the least-squares normal equations to determine the residual variations. A matrix inversion routine will be used to reduce some of the initial data.

The data may be inconsistent with the above interpretation. In this case it may be necessary to alter the scheme of calculation.

1439 Psychology. Cognitive Similarity and Communication. This problem concerns the prediction of interpersonal communication effectiveness. A series of ten concepts are rated on fourteen adjective scales (7-point scales) by thirty individuals. The ratings by individual A are compared with the ratings of individual B. Their "cognitive similarity" is obtained by three procedures: (a) correlate the ratings of A and B; (b) compute a D-matrix for B, and correlate the two D matrices; (c) compute a matrix of intercorrelations for the fourteen scales for individual A and a similar matrix for B and correlate the matrices.

The Illiac will be used to compute the following items: 435 correlation coefficients with N = 140; 30 D matrices and the 435 correlation coefficients between them; 30 intercorrelation matrices (N = 10; 14 variables) and the 435 correlation coefficients between them.

1440 Speech, University of Indiana. Semantic Differential Study. The meanings of certain speech concepts as measured by Osgood's Semantic Differential have been recorded. A twenty-nine variable factor analysis on this data is to be performed.

1441 Physics. Polarization Integral. The present integral arises in connection with a problem of point charges embedded in a charge plasma. We have a function of y, ξ, and R which must be integrated numerically over y for a number of values of the parameters ξ and R. Library subroutine E3 is used to perform the integration.

1442 Electrical Engineering. Q of a Resonant Cavity. The Q factor of a cylindrical resonant cavity is given by an implicit equation involving complex functions

of the free parameters of the cavity. In the limit of small values of one parameter, the complex equation can be reduced to two coupled equations which can be iterated to find Q. When Q is found by the approximate reduced equations, it is checked in the original complex equation. About one-hundred and fifty different combinations of parametric values will be used.

The reduced equations to be iterated are:

$$\frac{\mathrm{Sin}\ T}{2T} = \frac{[(\frac{NT}{y})^4 \frac{1}{4}(M-\frac{K}{Q})^2 - \frac{\mathrm{Sin}\ 2y}{2y}](\frac{K}{Q} + \frac{3M}{2Q^2}) - (\frac{M}{Q} - \frac{2K}{Q^2})(M - \frac{K}{Q})(\frac{NT}{y})^2 \frac{1}{2}(1 + \frac{\mathrm{Sin}\ 2y}{2y})}{[(\frac{NT}{y})^4 \frac{1}{4}(M-\frac{K}{Q})^2 - \frac{\mathrm{Sin}\ 2y}{2y}](M - \frac{2K}{Q}) + (K + \frac{3M}{2Q})(M - \frac{K}{Q})(\frac{NT}{y})^2 \frac{1}{2}(1 + \frac{\mathrm{Sin}\ 2y}{2y})}$$

$$\frac{1}{Q} = \frac{M}{K} \frac{\frac{1}{y}(\frac{NT}{y})(1 + \frac{\mathrm{Sin}\ 2y}{2y})(\cos^2 \frac{T}{2} + \frac{T^2}{Q^2}) + \frac{1}{2}(\mathrm{Sin}\ T - \frac{3T}{Q^2})[\frac{\cos^2 y}{y^2} + (\frac{NT}{y})^4 \frac{1}{4}(M^2 + \frac{K^2}{Q^2})]}{\frac{1}{4}(\frac{NT}{y})(1+\frac{\mathrm{Sin}\ 2y}{2y})(\cos^2 \frac{T}{2} + \frac{T^2}{Q^2}) + M^2\ \mathrm{Sin}\ T\ \frac{1}{4}(\frac{NT}{y})^4 + (T + \mathrm{Sin}\ T)[\frac{\cos^2 y}{y^2} + \frac{1}{4}(\frac{NT}{y})^4(M-\frac{K}{Q})^2]},$$

where y, K, M are free parameters related by

$$\frac{NT}{y} = \frac{1 + \frac{M}{4Q(K-.7508)}}{\sqrt{K-.7508}} .$$

1443 T Education. Prediction of Student Teaching Effectiveness. For the past two years data has been collected on student teachers in music education. The data gathering instruments consist of psychological tests, college grades, and observational rating scales of teaching effectiveness. The problem is to determine the reliability of raters, to check the validity of the psychological tests and college grades against the criteria of teaching effectiveness, and to select and to determine the effectiveness of the variables which can be used as the predictors of teaching effectiveness. The statistical procedures to be followed will be that of zero order and multiple correlations.

1444 T Physics. Lattice Sum. The problem involves the interaction between the quadrupole moment of an indium lattice ion and the electric field gradient produced by the other ions fixed at lattice sites in the crystal. The quantity which Illiac is to compute is

$$\sum_i \frac{3Z_i{}^2 - r_i{}^2}{r_i{}^5}$$

where all the ions within a sphere of fixed radius are included. The increments in the sum due to including increments in the spherical volume are computed and this will provide an estimate of the accuracy of the result.

1445 T Economics. Statistical Analysis of Investment Determinants. Investment models using capacity utilization and rate of profits as independent variables are to be tested. Multiple regression methods are to be employed and the library routine K-14 is to be used.

1446 Institute for Research on Exceptional Children. Role Playing Research. The purpose is to determine the changes in the meaning of occupational concepts produced by role playing human relations job-problems. Several instruments were administered before and after role playing and the analyses are of the differences in semantic differential scores. D^2 statistics for each concept and components for each instrument are to be obtained from Illiac. Standard programs will be used.

1447 Economics. Generation of Economic Data. In this problem autocorrelated economic data is generated in order to determine the effect of autocorrelation on the various methods of parameter estimation in economic models.

Exogenous variables and shocks are generated according to the following equations:

$$Z = \begin{bmatrix} B_1 Z_1 \\ B_2 Z_2 \\ \cdot \\ \cdot \\ \cdot \\ B_g Z_g \end{bmatrix} + P_2 R_2 + M_2$$

$$U = \begin{bmatrix} C_1 U_1 \\ C_2 U_2 \\ \cdot \\ \cdot \\ \cdot \\ C_f U_f \end{bmatrix} + P_u R_u + M_u$$

and endogenous variables are computed according to the following equation:

$$Y = \sum_{i=1}^{f} D_i Y_i + EZ + \sum_{i=1}^{g} E_i Z_i + FU + K,$$

where,

Z = vector of exogenous variables,

U = vector of shocks,

Y = vector of endogenous variables,

Z_i = vector of lags of the ith z,

U_i = vector of lags of the ith u,

Y_i = vector of lags of the ith y,

R_2 and R_u = vectors of random normal deviates,

$M_2, M_u, K, B_1, B_2, \ldots B_g, C_1, C_2, \ldots C_f$ are vectors of constant values,

$D_1, D_2, \ldots D_f, E, E_1, E_2, \ldots E_g, F$ are matrices of coefficients in the reduced forms.

1448 Institute for Research on Exceptional Children. Cue Utilization - Brain Damaged. The effect of perceptual cues upon the attempted solution of a problem was studied using brain damaged children. The experimentally manipulated variable was the relationship between a cue and correct reponse; however, no perceptual cue was necessary for correct solution. A simple ability to count the number of cards placed in a box was sufficient for solution since the children had to discover that their task was to place two successive cards into one box and the next two cards into the other box — the double alternation problem. Three perceptual cues were simultaneously present — color, number, and form — as printing on the face of the card. No cue was necessary for problem solution; however, for some groups one unnecessary cue was useful in that there was a correspondence between correct placement of the card and that cue, e.g., blue should be placed in the left box. Nevertheless, the children in these groups had to discover which cue had this relationship. For other groups no cue feature corresponded to correct placement 100% of the time. All groups were given the problem to solve using a cue deck and also using a blank deck. Thus transfer — both cue to blank and blank to cue — was studied.

Computations will be made of probabilities for individual, pairs, triplets, and sets of four responses. These will be analyzed in terms of $-p \log p$ values.

1449 T Agricultural Economics. Correlation Analysis of Wheat Consumption. This problem is designed as a correlation analysis of the domestic consumption of wheat as food in the United States. The results are to be used as evidence of whether to accept or reject a hypothesis.

The mathematical method to be used is the K16 standard library routine.

1450 Mathematics. The Existence of a Projective Plane with 11 Points on a Line. The problem of the existing of the projective plane is investigated under the assumption that there exist six points in the plane, no three of them on one line such that any other point of the plane lies on a line joining some two of the six basic points. Under this condition there are twenty-three lines in the plane which are arbitrary up to notation. Furthermore, some other lines are partly determined. The Illiac will be used to compute these lines.

1451 T Chemical Engineering. Least Squares Fittings. Theoretical boiling bubble growth rates in binary mixtures have been published by Scriven. By means of high speed motion pictures taken through the microscope, experimental data on these growth rates are being determined.

This computer program is to be used to reduce the measured variables radius (r) and time (θ) to the parameters β and n of an equation such as Scriven proposed by least squares fitting.

1452 Animal Science. Odd Perfect Numbers. This is a calculation of a lower bound for the number of prime factors in the successive odd perfect numbers. Such numbers are not known to exist, and calculation of the necessary number of prime factors will help in considering how to proceed toward their discovery.

Table I shows the distribution of Illiac machine time for the month of June.

TABLE I

	Hrs:Min	
Regular Maintenance	25:44	
Unscheduled Maintenance	15:15	
Drum Engineering	37:00	
R.A.R.	4:34	
Leapfrog	37:57	
Library Development	15:39	
		136:09
Use by Departments		
Demonstration	2:26	
Classes	3:16	
Agricultural Economics	7:37	
Agronomy	6:55	
Animal Science	4:47	
Astronomy (NONR 1834(22))	:39	
Business Economics and Business Research	1:36	
Bureau of Educational Research (12-20-60-482)	:06	
Bureau of Educational Research	17:54	
Chemistry	65:35	
Commerce	:22	
Control Systems Laboratory	53:52	
Dairy Science	:02	
Education (44-20-70-312)	1:26	
Education (Inst. for Exceptional Children)	:47	
Education	:03	
Digital Computer Laboratory	7:57	
Electrical Engineering (AF-6079)	1:47	
Electrical Engineering (SC-73163)	1:24	
Electrical Engineering (NSFG-67421)	:43	
Electrical Engineering	18:52	
Economics (NSFG-7056)	2:15	
Economics	:15	
Geology	1:29	
Geological Survey	3:09	
Institute of Commercial Research (PH-9067C)	6:00	
Institute of Commercial Research	:11	
Marketing	:54	
Jewish Hospital	:47	
Mathematics	:14	
Mechanical Engineering (Ord.1980)	:06	
Mechanical Engineering	:14	
Michael Reese Hospital	:05	
Natural History Survey	1:57	
Physical Education	1:40	
Physics (NONR 1834(12))	5:17	
Physics (NSFG-5970)	:10	
Physics	14:56	

(continued on next page)

TABLE I

Use by Departments (cont'd)

	Hrs:Min		
Psychology (AF49-(638)371)	16:36		
Psychology (ONR 1834(12))	9:18		
Psychology (PH-1774)	:39		
Psychology (MH-7289)	:13		
Psychology	12:51		
Sanitary Engineering	:05		
Sociology	13:58		
Student Counseling	1:21		
University of Ottawa	:57		
Structural Research (A.A.S.H.O. Road Test)	13:04		
Structural Research (AF-464)	6:17		
Structural Research	94:10		
University of Sydney	1:56		
Theor. and Applied Mechanics (Ord.593.I.C.)	3:34		
Theor. and Applied Mechanics	1:47		
State Water Survey (SC 75055)	3:16		
State Water Survey (NIHG-4007)	:29		
State Water Survey	2:13		
Zoology	:23		
		420:52	
			557:01

Error Frequency and Analysis

The Illiac is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive for an error standpoint to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind a summary table has been prepared, using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:30 - 6:30 period (when the machine is checked), if no errors are to be found, the time is given to the "running column".

Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for June.

TABLE II

Arithmetic		4
Drum		17
Unknown		11
Reader		7
Memory		5
Control		2
Power Supply		5
Punch		1
Camera		2
	Total	54

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/1/59	20:19	2:01	1:40	3	(1) Arithmetic error (2) Drum error (3) Unknown	0	1:21	0
6/2/59	21:49	:11	2:00	2	(1) Reader "B" error (2) Reader "H" error	0	:52	0
6/3/59	22:03	:02	1:55	2	(1) Reader "G" error (2) Reader "G" error	0	:51	0
6/4/59	21:02	:02	2:56	2	(1) Memory error (2) Unknown	0	:50	1
6/5/59	21:40	:28	1:52	3	(1) Unknown (2) Drum error (3) Arithmetic error	0	2:48	0
6/8/59	21:36	:29	1:55	3	(1) Drum failure (2) Control - white switch (3) Reader "F" failure	0	:40	0
6/9/59	21:00	:00	3:00	0		0	3:30	0
6/10/59	21:12	:00	2:48	0		0	:39	0
6/11/59	18:40	3:04	2:16	7	(1)(2)(3) Power supply error (4) Reader "E" error (5)(6) Unknown (7) Drum	0	1:01	0
6/12/59	16:16	4:51	2:53	4	(1)(2) Drum failure (3)(4) Memory error	0	:39	0
6/15/59	20:51	:00	3:09	0		0	1:35	0
6/16/59	21:38	:02	2:20	2	(1) Punch "3" error (2) Drum error	0	:39	0
6/17/59	21:04	:17	2:39	2	(1) Reader "G" error (2) Drum failure	0	:40	0

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
6/18/59	20:50	:39	2:31	2	(1) Drum failure (2) Power supply failure	0	:49	0
6/19/59	19:28	2:51	1:41	5	(1) Power supply failure (2) Drum failure (3) Arithmetic error (4) Memory error (5) Unknown	0	:19	0
6/22/59	22:58	:00	1:02	0		0	1:01	0
6/23/59	19:22	1:37	3:01	5	(1)(2) Camera errors (3) Unknown (4) Drum failure (5) Memory failure	0	1:21	0
6/24/59	14:45	6:43	2:32	6	(1) Arithmetic error (2) Drum error (3) Drum error (4) Unknown (5) Unknown (6) Unknown	0	:40	0
6/25/59	19:10	3:20	1:30	3	(1)(2)(3) Drum failures	0	:34	0
6/26/59	20:51	:30	2:39	0		0	:40	0
6/29/59	20:35	:23	3:02	2	(1) Control error - white switch (2) Unknown	0	:50	0
6/30/59	20:59	:01	3:00	1	(1) Drum error	0	:59	0
TOTALS	448:08	27:31	52:21	54		0	23:18	1

PART IV
IBM 650 USE AND OPERATION

New 650 Codes

During the month of June two new programs were added to the Digital Computer Laboratory IBM 650 Library.

Y5'-31' Magnetic Tape Quality Analysis. Y5' reads the tape on Unit 0 (8010), either numerically or alphanumerically as specified, until a tape mark is encountered, checking each record (record length constant for the tape), for the number of passes (up to 50), necessary for an error free tape read. Information indicative of the condition of the tape is printed via the 407. When the program is finished the tape is rewound. Magnetic labels of the same mode and length as the tape records are acceptable.

(R. H. Flenner)

P6'-32' Matrix Punch Routine. This closed subroutine punches out a matrix stored by rows sequentially on the drum. Essentially, it partitions the matrix into 7 column sections and punches section 1, then section 2, etc.

(M. T. Gray)

IBM 650 Usage

During the month of June problem specifications for the 650 are:

17' Education and Statistical Services Unit. Characteristics of Gifted Children. Gifted and non-gifted children from University High School, Franklin Junior High School and Urbana Junior High School have been given a series of tests. The results of these tests are to be compared with each other and with the I.Q.'s of the students. It is hoped that we can get some significant indication as to the relationship between I.Q. and a) tactile sensitivity, b) aesthetic perception, c) creativity, d) art ability, and relationships between these tests.

It is also hoped that we can get some measure of the validity of the Kole's

Black Test as a measure of art ability, and a measure of the Lambert Brittain test as a measure of creativity.

The product moment correlations and 'T' tests will be computed.

18' Theoretical and Applied Mechanics. Velocity and Acceleration Determination. The problem involves the analysis of experimental displacement-time records obtained in a fundamental study of water-exit hydroballistics. The kinematic behavior of a body as it passes from water to air is to be computed. Its position is measured at equal time intervals and by evaluating a fine point parabola, the velocity and acceleration are to be found.

19' Bureau of Institutional Research and Statistical Services Unit. Bureau of Institutional Research Statistical Reports. The data for the following reports are collected via a questionnaire sent to the academic staff on the Urbana and Chicago campuses once during the fall semester and again during the summer. The questionnaires are sent out early in each of the teaching periods and 650 time is needed in September and December for their analysis.

In general, each of the analyses will be categorized into campus, college and department groups. Further classification within each of these groups together with report titles are:

1) Analysis of class size. A distribution of the number of registrations per course section together with the salary cost of the small sections by type of instruction.

2) Analysis of staff activities. A distribution by source of funds and type of departmental activity, and by the number of staff and the full-time equivalence of staff by rank.

3) Details of individual courses. Analysis of student time in class, instruction time and cost per course.

4) Analysis of teaching loads. A distribution of departmental and major division teaching loads by level and type of instruction.

5) Teaching loads by academic rank. A distribution of course information including full-time staff equivalence for each teaching activity by academic rank.

Computations other than compiling the data into the various categories consist of prorating salary cost and full-time work loads for each category and computing percentages or ratios between the various totals.

20' Chemistry. Comparison of 3 Proton N.M.R. Spectra. The program is to take an observed n.m.r. spectrum, normalize it to a certain scale and compare it with a series of calculated spectra read in on cards. The machine prints out the spectra which fit best and a criterion of fit.

21' T Agronomy. Plastic Fitting Losses. The program is used to calculate, by three methods, the head loss due to various types of pipe fittings, i.e. a coupler, ell, and reducer. The output is then used in an analysis of variance.

22' T Civil Engineering. Numerical Integration by β Method. This is a program for numerical integration of second-order differential equations for single-degree freedom systems by use of the Newmark β Method. Several short routines will be used to test the program.

23' T Education. Prediction of Student Teacher Effectiveness. For the past two years data has been collected on student teachers in music education. The data gathering instruments consist of psychological tests, college grades, and observational rating scales of teaching effectiveness. The problem is to determine the reliability of raters, to check the validity of the psychological tests and college grades against the criteria of teaching effectiveness, and to select and to determine the effectiveness of the variables which can be used as the prediction of teaching effectiveness. The IBM 650 will be used in computing the means and standard deviations for groups of raters and the coefficient of correlation between raters.

24' Psychology. Predicting Advanced Stages of Academic Learning. The research is an attempt to determine whether or not different abilities are involved in different stages of complex learning. The 650 will aid in this research by performing the statistical operations that will allow the determination of differential function of a number of abilities as measured by existing and newly devised measures of such abilities. The specific operations will be to compute intercorrelation with all tests and learning stages and to compute the multiple regression between tests and stages.

Table I' shows the distribution of the IBM 650 machine time for the month of June.

TABLE I'

	Hrs:Min		
Regular Maintenance	13:55		
Unscheduled Maintenance	15:27		
Air Conditioning Maintenance	65:03		
Library Development	13:44		
Wasted	30:24		
		138:33	
Use By Departments			
Statistical Service Unit	64:02		
Theor. and Applied Mechanics	2:39		
Civil Engineering	:46		
Agronomy	1:07		
Chemistry	1:09		
Classes	:21		
		70:04	
			208:37

Error Frequency and Analysis

The IBM 650 is normally on from 8 a.m. to 5 p.m. The machine is used for preventive maintenance from 8 a.m. to 12 noon on Wednesdays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for June.

TABLE III'

533	13
IAS	2
407	3
Tape Unit	3
Air Conditioning	2
Total	23

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
6/1/59						9:00	Machine not turned on due to pipes being wrapped on the air conditioning installation.
6/2/59						9:00	
6/3/59						9:00	
6/4/59						9:00	
6/5/59						9:00	
6/8/59	4:52		1:30	2:38	1		Bad relay in the 533 but not determined until June 10th during Scheduled Engineering.
6/9/59	3:45			5:15	0		
6/10/59	1:26	5:55		1:39	0		
6/11/59	3:51		:32	4:37	1		Bad tube in IAS
6/12/59	3:11		2:43	3:06	0		This Repair Time is additional time spent in finding trouble on the 11th.
6/15/59	3:15			4:52	1	:53	Air conditioning shut off automatically, probably due to overload.
6/16/59	5:17		:32	3:22	1		Appeared to be IAS but cause not determined.
6/17/59	2:29	4:00	:20	2:11	2		(1) and (2) 533 standard board incorrect
6/18/59	9:08			:09	8		Could not pin down - suspect cause was found on June 19th.
6/19/59	7:45		1:00	:15	2		(1) 533 read brush was loose. (2) Card jam in 533.
6/22/59	8:02			:58	0		
6/23/59	6:42		2:02	:31	3		(1) Tape unit. (2) (3) 407 when on line.
6/24/59	5:01	4:00	5:10	:03	1		407 had a bad relay
6/25/59	5:44		1:38	:28	2	1:10	(1) Tape unit when shifting from high to low speed on rewind. (2) Air conditioning overloaded.

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
6/26/59	13:20			:20	1		Tape unit when shifting from high to low speed on rewind.
6/29/59						9:00	Machine not turned on due to pipes being wrapped.
6/30/59						9:00	
TOTALS	83:48	13:55	15:27	30:24	23	65:03	

PART V

GENERAL LABORATORY INFORMATION

Personnel

The personnel associated with the department and, hence, the contributors to this report are:

Bahls, James E., Jr. Laboratory Mechanic
Baur, John W., 1/3-time Research Assistant
Beardwood, Miss Jillian E., 1/2-time Research Assistant (through June 15)
Bivins, Robert L., 1/2-time Research Assistant(through June 15)
Blencoe, Robert W., Computer Operator I
Bowes, Mrs. Doris E., 1/2-time Research Assistant
Buenger, George E., 1/2-time Research Assistant (through June 15)
Carter, Clifford E., Electronics Engineer
Chow, Yuan S., Research Associate (through June 15)
Clark, Miss Helen B., Secretary
Cummins, Richard L., Research Assistant
Davenport, Mrs. Margery S., Clerk-Stenographer II (started June 8)
Dickman, Kern W., Research Assistant
Ellsworth, Mrs. Jean E., Clerk-Stenographer III
Fileccia, John L., Electronics Technician I
Flenner, Ross H., 1/2-time Research Assistant (through June 15)
Fosdick, Lloyd D., Res. Asst. Prof. of Physics
Foster, Merlin J., Computer Operator I
Foulk, Clinton R., 1/2-time Research Assistant (through June 15)
Gear, Charles W., Research Assistant
Gillies, Donald B., Res. Asst. Prof. of Appl. Math.
Gray, Mrs. Mary T., Research Assistant
Guckel, Henry, 1/2-time Research Assistant (through June 15)
Gustafson, Ronald A., Electronics Technician I
Halton, John H., 1/2-time Assistant (through June 15)
Handscomb, David C., Research Assistant (through June 30)
Huffman, W. Logan, Computer Operator II
Hunt, Miss Rosalie J., Tab. Machine Operator I
Johnson, Noel H., Research Assistant
Kerkering, Thomas E., Sr. Laboratory Mechanic
Krabbe, Shirlie P., Electronics Technician II for Illiac
Kunihiro, Toshiro, Res. Asst. (started June 16)
Leslie, James D., 1/2-time Research Assistant
Lierman, Richard A., Electronics Technician I
Lindquist, Arwin B., 1/2-time Research Assistant (through June 15)
Liu, Chao-ning, 3/4-time Research Assistant
Lopeman, Harold E., Electronics Engineer for Illiac

Marcer, Peter J., 1/2-time Research Assistant (through June 15)
Meagher, R. E., Head of the Laboratory (on leave beg. April 1, 1959)
Metze, Gernot A., Research Associate
Michael, George W., Administrative Assistant
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Saathoff, Norma I., Computer Teletype Operator
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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

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July, 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. 52 Bit Shifting Register

During the month the work on the shifting register has been directed toward obtaining accurate drawings for all parts of the unit as a prerequisite to construction. It was decided to build two types of control: one synchronous control to drive the unit as fast as possible and one speed-independent control. Since both the 60 mμs and 120 mμs controls mentioned in the May report are synchronous, the logical diagram and a complete circuit diagram for a speed-independent control were drawn. In this speed independent-control, the down gate signal (d) is not initiated until all three reply signals, (left (L'), right (R'), and up (μ")) indicate that the drivers have changed to the new state. Since all up shifts are independent of the right-left selectors, the up shift and the change in the state of the right-left selectors can occur simultaneously. A preliminary estimate of operating time is 320 mμs for four operations (up-down left-up-down right). This time estimate assumes that the signal propagation velocity is the velocity of light (1 mμs/foot) and it assumes that all circuit operating times are the maximum observed. The actual velocity will be lower which will lengthen the cycle time and many of the operating times will be shorter; it is quite possible that these two effects will be approximately equal giving an operating time quite close to the estimate.

In preparation for constructing the shifting register, all of the appropriate schematics were checked and parts ordered. Only two Zener diodes remain unordered. These Zeners (5.5v and 6.5v) must be accurate in voltage to ± 1%. Several companies have such components advertised and as soon as an acceptable supplier is selected, these items will be purchased.

(R. E. Swartwout)

2. Testing Program for High-Speed Transistors

At the end of approximately 1800 hours of aging, a batch of 60 GF-45011 transistors (Western Electric) show properties that can be divided into three categories, illustrated by the sketches showing output characterisitics. Type A is referred to as normal behavior, Type B is similar to a thyristor, and is useless in our switching circuits, and Type C displays a definite hysteresis loop. The line dividing Type A and Type C is somewhat arbitrary. Type B behavior is clearly quite different.

Type A: Normal.

The negative slope region shown on the Type A set of characteristics has been studied and correlated qualitatively with two well-known effects, pre-avalanche multiplication and the current dependence of alpha.

The negative slope parts of the characteristics occur when the small-signal alpha is greater than one. The multiplication phenomenon that causes this occurs directly in the collector space-charge region, is dependent upon voltage but not current, and is relatively fast. The exact shape of the $I_B = 0$ line varies somewhat from unit to unit. If the load line intersects this curve at three points, switching times may be reduced considerably. Experiments are being prepared to evaluate the seriousness of this effect so that a new specification can be placed on the transistor if it proves to be necessary. Both Western Electric and Texas Instruments appear to be willing to accept a new specification based on the location of the $I_B = 0$ line.

Type B: Thyristor-type behavior.

During the course of the 1800 hour aging test, eight of the original 60 transistors failed destructively, and one failed but was not destroyed. Point-by-point measurements showed this transistor to be of the B type. The significant part of the characteristics is the fact that all values of I_B converge to a common line, approximately straight and going through the origin, indicating internal saturation. Once a transistor has changed to this type of behavior, it will fail to operate in our switching circuits, for one of the following three reasons. At best, it will require very much longer (milliseconds) to switch from high collector current to cut-off. More probable is the tendency to remain at high current and fail to switch at all. As a third and highly probable alternative, it will swing to an excessively high base current and destroy itself.

Although we cannot be entirely sure, the evidence suggests that the eight transistors that failed destructively were burned out as a result of shifting to Type B behavior. The test circuits have been modified to prevent burnout in the future when units make this transition. Further aging tests should show how frequently this behavior will occur.

All our tests convince us that the thyristor-like effect is caused by back-emission from the metal header into the bottom of the collector body. The physical process is current sensitive as well as voltage sensitive, and has a relatively long time constant.

Type C: Hysteresis

Very little is known about the probable cause or effect upon switching circuits of this type of behavior. Preliminary tests suggest that units showing a pronounced hysteresis loop are considerably slower. Since the loop shows up at 60 cycles, one is inclined to guess that it is associated with the back-emission process of the Type B units. Further experiments and further aging tests will be required.

(T. A. Murrell)

3. Arithmetic Unit Design

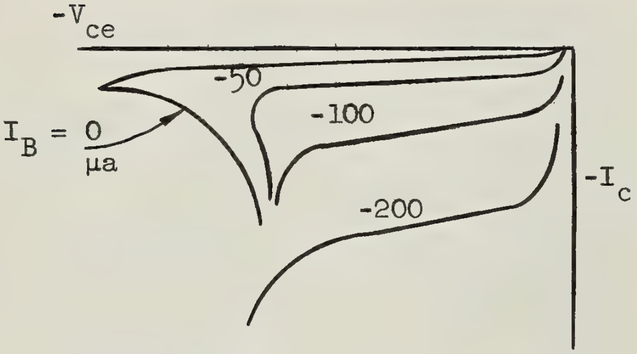
The logical layout for one entire quaternary digital position in the arithmetic unit was prepared, together with a connection chart for the shift gates, to indicate how gating is to vary with the various logical and arithmetic operations.

The transistor count for one such quaternary position, which is to be iterated 23 times, is 200. This does not include the cost of the Carry Generator, which is not iterated on a quaternary basis. The entire carry generator requires 260 transistors.

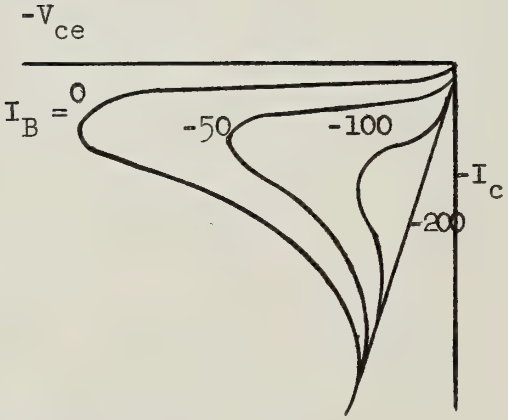
(R. R. Shively)

4. Core Storage Unit

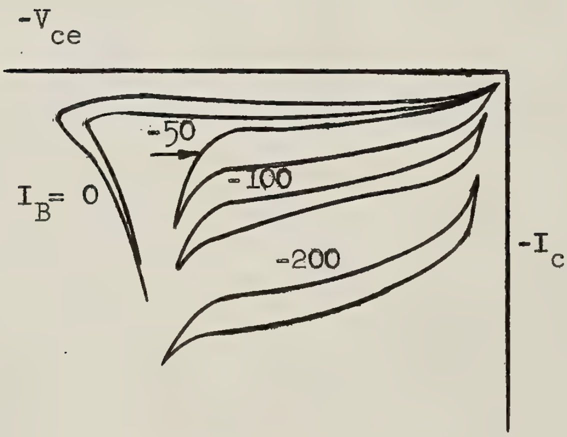
The operation times of the driver described in the May Monthly Report were disappointing enough to initiate a search for a faster driver circuit using the same sort of transistors and having almost the same capabilities. From all indications, most of the time in last month's circuit went into the driver transistor with the load in the collector. It would seem reasonable, then, to put the load in the emitter of the driver transistor to save the collector delay time. However, a nonlinear load such as cores in the emitter would require some sort of feedback to regulate the emitter



Type A: Normal



Type B: Thyristor-like



Type C: Hysteresis

current further, the voltage swing across the load now must be less to keep the base driving voltage swing at a reasonable level. Such an emitter follower, feedback, lower load voltage swing driver is being calculated.

(John L. Muerle)

Two prototype variable voltage regulators were designed; built and tested. They have the following characteristics

	Voltage Range	Max.Current	Load Regulation	Drift
POSITIVE				
	+2 to +5	2 amperes	internal resistance = .25Ω	1%
	+5 to +10			
	+10 to +15			
	+15 to +20			
	by plug-in boards			
NEGATIVE				
	-1 to -6	2 amperes	internal resistance =.15Ω on just three ranges and =.3Ω on last	1%

The regulators need +25 and -25 volts supplies.

The design of a power transistor tester has been started.

(J. D. Leslie)

From a study of single and repeated sets of pulse experiments it appears that, for a magnitude of the disturb pulse exceeding 50% of the threshold field, irreversible magnitization can be continuously accumulated for as many as one thousand such pulses.

The difference between partial select voltages generated by two cores in different states is being studied.

(A.Y.F. Wong)

5. Input-Output and Auxiliary Storage

The Ampex FR-300 Magnetic Tape Unit was delivered early this month. Several necessary schematics were not delivered until near the end of the month.

A remote control test unit was designed to test the performance of the tape handler, particularly with respect to possible mechanical resonances which might restrict the timing of certain control commands.

Under manual control, it was found that certain sequences of "forward" and "reverse" commands resulted in slippage of tape on a partially-filled reel, in such a manner that sharp transverse folds were created in the tape; these folds rendered portions of the tape unsuitable for reliable playback.

This difficulty appears to be due to the new type of magnetic tape furnished with the machine; this tape was recently developed and has a harder and more polished surface than that previously used by Ampex. We have been advised that the Ampex Corporation will alter or adjust our machine to permit reliable operation with this tape.

Construction of the programmed pulse train generator for use in testing read/write circuits, drop-out rates, etc., has been delayed by diode procurement difficulties.

(R. L. Cummins)

Recording circuits in the Ampex FR-300 tape recorder were checked. Attempts are being made to design a clock delay unit with 12 volts swing to clock eight channels on the tape. Drop out tests will be initiated as soon as the clock delay unit is completed.

(C. N. Liu)

The design of the 16 input OR gate for the programmed pulse train generator has been completed.

A previously built operation counter and running time recorder is being modified for use with the FR-300 tape unit.

(L. J. Peek)

PART II

MATHEMATICAL METHODS

In Taub's paper [Ann. Math. 62 No. 2. 1955] it was pointed out that is is impossible to satisfy a number of boundary value problems for the hydrodynamic equations with an analytic solution. In the supersonic case it has been shown how a piecewise analytic solution will satisfy the known conditions.

In the subsonic case a non-singular transformation of the form

$$\tan\beta = \frac{as}{bs+T}$$

$$R^{2\tau} = (as)^2 + (bs+T)^2$$

makes it possible to solve a further class of boundary value problems by means of the power series solution.

$$\xi_i = \sum_{k=o}^{\infty} R^K f_k^i(\beta) .$$

The linear differential equations for the F_k^i are

$$\frac{d}{d\beta} f_k^i(\beta) = f_k^i(\beta) \cdot A_k^{ij}(\beta) + C_k^i(\underline{f}_o, \underline{f}_i, \ldots \underline{f}_{k-1}).$$

These lead in some cases to an infinite shock curvature, which is practically implausible because of viscosity.

For small viscosities and shock curvatures, it has been shown that the Rankine Hugoniot equations are changed to

$$\xi_i(s,o) = \xi_i(s,o) + KF_i(s,o)$$

where $\xi_i(s,o)$ is the usual value derived from the R-H equations. The extra term makes it possible to find an analytic solution by Taub's method to a number of boundary value problems.

(C. W. Gear)

PART III

ILLIAC USE AND OPERATION

Illiac Usage

During the month of July specifications were presented for 20 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1453. Numbers followed by T are for theses.

1453 Astronomy. Escape Orbits from Star Clusters. The problem is to trace the orbit of a star that is influenced simultaneously by the attraction of a star cluster and the tidal force of the Milky Way. The stars considered have sufficient energy to escape from the attraction of the cluster, but escape can take place only along certain narrowly restricted directions. The question to be answered is how long such stars wander about before finding the escape corridor. The answer will determine the evolution of the cluster.

1454 Physics. Solution of a Differential Equation. The Runge-Kutta method will be used to solve a single first order differential equation.

1455 Digital Computer Laboratory. Circuit Analysis. This program is used to calculate the node voltages and branch currents in the static equilibrium case for an arbitrary circuit composed of resistors, diodes and transistors. The circuit configuration and the values of the circuit elements are specified on a data tape.

The problem is solved by an iterative process in which the variation in the current sum into a node corresponding to a variation in the node voltage $\left(\frac{\delta\sum I}{\delta V}\right)$ is calculated and the node voltage is then corrected in an attempt to make the current sum into the node equal to zero. This correction is simply a linear extrapolation based on the derivative $\frac{\delta\sum I}{\delta V}$.

1456 Dairy Science. Effects of Crossbreeding on Milk and Butterfat Yield. This problem concerns the analysis of the milk and fat production data gathered in the dairy cattle crossbreeding experiment over the past decade.

All records are to be adjusted for the year to year differences caused by environmental change, by a method described by Dr. C. R. Henderson. This involves solving a set of equations containing the year of birth, year each record commenced,

repeatability and total production for each cow. These equations will be reduced in number on a desk calculator to a set of eleven simultaneous equations. This matrix will then be inverted, using program M13 and the inverse will be used to solve for the yearly effects and their standard errors.

Following the adjustment of each record, the lactation data will be fitted to the model:

$$Y_{ijkl} = m + a_i + b_{ij} + c_k + ac_{ik} + bc_{ijk} + e_{ijkl} ;$$

where, m is the general mean, a_i the effect common to all progeny of the ith breed of sire, b_{ij} the effect common to all progeny of the jth sire of the ith breed, etc.

1457 Dairy Science. The Effect of some Weather Factors on Daily Milk and Fat Production. The deviations from fitted quadratics at an average of ten days during a total of 101 lactations have been calculated and summed within lactations using a routine written by H. W. Norton. It is planned to inject these deviations into a multiple regression model to solve for linear and quadratic effects of certain weather factors on these deviations from the fitted quadratics.

1458 Chemistry. The Integration of a Second Order Differential Equation by a Ninth Order Process. The program is intended to solve the radial Schrödinger equation, and, in general, equations of the form $u'' = gu + q$ where $g(r)$ and $q(r)$ are specified. The asymptotic behavior of $u(r)$ near the origin ($r = 0$) and for large r is supposed to be known (in terms of the forms of the functions g and q).

A ninth order integration formula (based on the eighth order Numerov formula) is used and the equation is integrated "inwards from both ends (0 and ∞)", starting with the known asymptotic forms, and the solutions fitted over an overlap region to give the required solution. Automatic adjustment of the step length is provided.

1459 Structural Research. Problems of Bending of Thin Elastic Plates. Elastic plates of rectangular shapes subjected to loads normal to the plane of the plate with different boundary conditions, including plates continuous over several supports, will be investigated.

The problem of bending of plates, neglecting the effects of strains in the plane of the plate and also direct strains normal to the plane of the plate, involves the determination of solutions to the following differential equation:

$$\frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} = p(x,y)/N$$

with particular boundary conditions. The solutions for w will be determined by the use of the calculus of finite differences, with the equations to be solved by L7.

1460 Animal Science. Frequency Checking of Data Tapes. This program is a routine check on data tapes which consist of a number of factors of equal length. Any factor with the wrong number of components is considered to be in error.

1461 Agricultural Economics. Multiple Regression. This research is concerned with the market potential for feed grain concentrates in Illinois. A multiple regression analysis of the effect of rainfall in various states on corn yields will be performed.

1462 T Agricultural Economics. Hay Pelleting. This project is a study of methods of making hay pellets. The Illiac will be used to analyze the experimental data by analysis of variance.

1463 Psychology. Children's Behavior Problems. Fifty-five behavior problems have been assessed for approximately 250 children at each of four age levels. For each of the four groups, the problems are to be intercorrelated, factor analyzed, and the factors rotated to simple structure. Intercorrelations between columns of loadings will then be computed to facilitate comparison of the factors.

1464 Animal Science. Potassium Requirement of Growing Pigs. The problem is to ascertain the potassium percentage in the ration such that increased potassium gives no response. Illiac will perform the arithmetic of least squares for fitting a line which rises linearly with the potassium level until the requirement is reached and is horizontal thereafter.

1465 T Electrical Engineering. Nonlinear Feedback Systems. The present plan is to investigate the statistical properties of Nonlinear Feedback Control Systems by setting up the analogue of the system on the Illiac. Probability distributions will be used as the input to the systems. Some things to be calculated are:

1) Probability distribution of output of system.
2) Probability of error signal exceeding a specified value in a given time.

1466 T Civil Engineering. Buckling Interaction. This is the solution of a system of fifteen simultaneous nonlinear algebraic equations associated with buckling interaction by the use of Newton's method applied simultaneously to all variables.

1467 Veterinary Physiology and Pharmacology. Irradiated Food Project. The determination is made of the wholesomeness of irradiated food. The data to be analyzed are hematological studies made during a two year feeding study.

1468 Astronomy. Basic Escape Rate from Star Cluster. The relaxation of a stellar velocity distribution is described by an integro-differential equation that involves second derivatives and three different integrals. The requirement that this equation have a steady-state solution with a cut-off at the escape velocity leads to an eigenvalue problem involving a fourth order system of differential equations. The resulting eigenfunction is a basic velocity distribution that may be put into another relaxation equation to determine the rate of escape of stars of greater or less than average mass. This second problem leads to eigenvalue searches in a second order differential equation.

Once the basic eigenvalue is found, the basic velocity distribution can be reproduced. The eigenvalue search is performed by a routine that uses interpolation and extrapolation to converge rapidly on the correct value. The second order problem will be solved for a number of different star masses.

1469 Physics. Mathematical Spline. This is a closed subroutine which will fit a given set of points by matched cubics, the so-called "beam fit" or mathematical spline.

1470 Mining and Metallurgical Engineering. Least Squares. This is a least squares problem for fitting a polynomial of the form

$$y = Ax + Bx^3 + Cx^{-2}$$

to various sets of experimental data.

Automatic scaling is used for the generation of the normal equations to preserve accuracy, and a number of internal checks are provided against incorrect input data format and loss of significant digits due to ill-conditioned normal equations.

1471 Mining and Metallurgical Engineering. Linear Programming of a Coal Washing Plant. The purpose of the problem is to demonstrate that linear programming can be of value in scheduling the production for a particular coal washing plant in order to produce maximum net profit. The plant in question cleans 10,400 tons of raw coal per day, and can produce twenty-four final products and ten blends of these products. There is a choice of products to be sold and the way in which they are made. The model includes fifty-five equations and sixty-four structural variables.

1472 Sociology. Factor Analysis of Prisoner Orientations from Phi Analysis of Dichotomous Data. The first objective is to obtain the factor structure of a battery of forty-four dichotomous responses by inmates of Federal prisons indicating their present and past interests and problems in prison, and their perception of the interests of other inmates. Once the underlying dimensions or "ways of doing time" have been extracted from this raw data, individual factor scores will be obtained for each inmate to permit study of the effectiveness of these dimensions as predictors of certain criteria, such as success and failure on parole, and to see if the factors are related to background information on the inmates, so that "ways of doing time" might be predicted. Available routines in the statistical library of Illiac will be used for this study.

Table I shows the distribution of Illiac machine time for the month of July.

TABLE I

	Hrs:Min	
Regular Maintenance	48:30	
Unscheduled Maintenance	36:36	
Drum Engineering	35:17	
R.A.R.	8:23	
Leapfrog	34:24	
Demonstrations	:33	
Library Development	1:19	
		165:02

TABLE I
(cont'd.)

Use by Departments

	Hrs:Min		
Agricultural Economics	3:25		
Agronomy	9:19		
Animal Science	7:01		
Astronomy (NSFG-5512)	3:38		
Astronomy (NONR-1834(22))	:12		
Bureau of Educational Research (12-20-60-482)	:28		
Bureau of Educational Research	19:13		
Chemistry	36:35		
Coordinated Scientific Laboratory	54:42		
Electrical Engineering (AF-7069)	:24		
Electrical Engineering (SC-73163)	1:05		
Electrical Engineering (NSFG-22-401-266)	1:47		
Electrical Engineering (NSFG-7421)	:18		
Electrical Engineering	29:32		
Education	3:14		
Economics (NSFG-7056)	1:50		
Economics	:20		
Digital Computer Laboratory	37:31		
Geological Survey	1:04		
Institute of Commercial Research (PH-9067C)	1:07		
Institute for Exceptional Children	1:58		
Indiana University (Speech)	:17		
Mathematics	1:19		
Mechanical Engineering (ORD-1980)	:40		
Mining and Metalurgical Engineering (AF-3789)	:60		
Physical Education	:48		
Natural History Survey	:08		
Physics	19:50		
Psychology (44-32-66-312)	1:18		
Psychology (ONR-1834(11))	3:41		
Psychology (AF-49-638-371)	11:31		
Psychology (MH-7289)	:51		
Psychology (PH-1774	:37		
Psychology	29:52		
Physiology	:06		
Sociology	3:32		
Structural Research (AF-464)	10:07		
Structural Research (A.A.S.H.O. Road Test)	6:32		
Structural Research	70:50		
Sanitary Engineering	:09		
Theoretical and Applied Mechanics (ORD-593IC)	3:24		
State Water Survey (NIHG-4007)	:11		
State Water Survey (SC-75055)	1:24		
State Water Survey	1:41		
Zoology	:31		
Speech	:26		
Veterinary Physiology (MO-728-Off Sing. Gen.)	:07		
Eastern Illinois University (Botany)	:14		
Classes	8:21		
		394:10	
			559:12

Error Frequency and Analysis

The Illiac is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive for an error standpoint to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind a summary table has been prepared, using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:30 - 6:30 period (when the machine is checked), if no errors are to be found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for July.

TABLE III

Memory	12
Drum	17
Reader	2
Punch	2
Control	12
Power Supply	3
Unknown	8
Eng. run-over into Prod.	1
Total	57

Table II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP- TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/1/59	20:56	:01	3:03	1	(1) Drum failure	0	1:46	0
7/2/59	16:37	4:28	2:55	3	(1) Wire out of place in decoding ch. (2) Drum failure (3) Drum air conditioning	0	1:38	1
7/6/59	13:32	8:28	2:00	6	(1)(2)(3)(4) Drum failures (5)(6) White switch failures	0	1:04	0
7/7/59	21:46	:16	1:58	1	(1) Power supply short	0	:20	0
7/8/59	18:58	2:00	3:02	2	(1) Drum failure (2) White switch	0	:41	0
7/9/59	13:13	8:47	2:00	3	(1)(2)(3) Control	0	3:51	0
7/19/59	19:52	3:08	1:00	2	(1) Drum failure (2) Reader "H" error	0	:20	0
7/13/59	19:47	1:20	2:53	2	(1)(2) Unknown	0	8:41	0
7/14/59	18:54	2:04	3:02	4	(1) Unknown (2) Drum failure (3) Reader "B" error (4) Punch "1" jammed	0	1:02	0
7/15/59	15:00	5:59	3:01	3	(1)(2)(3) Memory errors	0	:58	0
7/16/59	20:03	:49	3:08	1	(1) Leapfrog 2^{-10} and 2^{-06}	0	:44	0
7/17/59	21:37	:35	1:48	1	(1) Leapfrog error, cause not noted	0	1:04	1
7/20/59	20:28	:39	2:53	2	(1) Eng. run-over into Production (2) Memory error	0	:40	0
7/21/59	17:45	5:13	1:02	3	(1) Memory 2^{-11} (2) Leapfrog, reason not noted (3) Unknown	0	:50	1
7/22/59	22:02	1:00	:58	1	(1) Memory 2^{-11}	0	:40	0
7/23/59	20:19	1:37	2:04	3	(1) Unknown (2) Drum failure, (3) Memory 2^{-33}	0	:55	0

Table II (cont'd)

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
7/24/59	14:37	8:30	:53	3	(1) Memory (several positions sensitive) (2) Drum Failure (3) Low Line Voltage	0	:41	0
7/27/59	16:41	4:31	2:48	2	(1) Memory 2^{-33} (2) Memory 2^{-33}	0	:41	0
7/28/59	17:48	2:21	3:51	8	(1) Memory 2^{-33} (2)(3) Memory 2^{-4} (4) 2,000 V. supply (5)(6)(7) White switch (8) Drum failure	0	1:23	1
7/29/59	20:02	:20	3:38	2	(1) Unknown (2) Drum Failure	0	:39	0
7/30/59	17:15	1:40	5:05	4	(1) Punch "4" (2) Drum failure (3)(4) White Switch	0	:40	0
7/31/59	20:06	:00	3:54	0		0	:40	0
TOTALS	407:18	63:46	56:56	57		0	29:58	4

PART IV

IBM 650 USE AND OPERATION

IBM 650 Usage

During the month of July specifications were presented for 12 new problems. Numbers followed by T'are for theses.

25' Coordinated Scientific Laboratory. Complex Number Arithmetic. A preliminary study of the use of the 650 for routine calculations involving electric networks is desired. This will be begun by writing an interpretive order floating point complex number arithmetic routine. It is anticipated that the routine will be faster than the IBM library routines because advantage can be taken of the additional equipment that this machine possesses. The speed of the interpretive routine will determine subsequent work.

26' T' Agronomy. Effect of Photoperiod on Growth and Flowering of Carnations. This research problem is a study of the effect of photoperiod on the growth and flowering of the carnation variety Sidney Littlefield. The research is designed to trace the effect of various day length treatments on the stock plants, on the cuttings in the propagation bench, and on the plants grown for the production of flowers.

27' Marketing. Factor Analysis of Food Expenditures of U. S. Households. Data has been obtained from about 10,000 U. S. households, each consisting of 13 household characteristics and 24 food expenditure totals. The correlation will be obtained and later subjected to further analysis.

28' Theoretical and Applied Mechanics. Tool Settings for Spherical Models. This problem concerns the tabulation of coordinates for simple geometric figures and is a rewrite of Illiac problem 933 to reduce printing time.

29' Agriculture Extension. Agriculture Extension Keeping Fit Study, Program 1. Daily measurements of various physical characteristics of students are made. From this information the body type and percentage of normal weight are both calculated and predicted on two occasions.

30' Agriculture Extension. Agriculture Extension Keeping Fit Study, Program 2. Standard score is to be calculated from a special program. The means and standard deviations are in tables by sex and age for 12 tests and by body size for 2 tests.

31' Business Office and Statistical Service Unit. Accounts Receivable. The 650 Computer will be used for updating a student account file on magnetic tape and computing penalty amounts for all delinquent accounts. Output from the machine will be a statement of account and a punched card to be returned with the payment on the student's account.

32' T' Institute of Labor and Industrial Relations and Statistical Service Unit. Occupational Attachment. This is a frequency count of 1-digit numbers. 825 frequency tables will be prepared for each of 4 equal sized subsamples within a total sample of 199. 150 frequency tables will be prepared for the total sample. On all frequency tables, frequencies and percentages will be computed.

33' Agronomy. Pasteurization and Radiation of Chickens. A factorial combination of pasteurization and radiation treatments was used to preserve chickens. The effect of the different preservation methods were then evaluated by organoleptic and chemical tests. These results are being subjected to analysis of variance to determine significant differences between treatments.

34' Agronomy. Sweet Corn Variety Testing. Evaluation of sweet corn varieties by using analysis of variance to determine if varieties differ significantly.

35' T' Physics. Least Squares Analysis of E. P. R. Spectra. The paramagnetic resonance spectrum of additively colored, KCl crystals is the superposition of three gaussian line profiles, each belonging to a separate color center and having its own characteristic decay time. A run consists of about twenty spectra taken with different decay times. The problem is to resolve the spectra into the component gaussians so as to determine the decay time of each by the method of least squares.

36' T' Digital Computer Laboratory. Integration of Hydrodynamic Equations. The equations of stationary (or pseudo-stationary) flow in polar coordinates defined on a set of skew axes are, in this problem, elliptic in the region of interest. Under the assumption of analytic flow we may integrate from a given line. The equations will be integrated by a first order method. In addition, using the power series method an attempt will be made to solve the two point boundary problem.

Table I' shows the distribution of the IBM 650 machine time for the month of July.

TABLE I'

	Hrs:Min		
Regular Maintenance	14:09		
Unscheduled Maintenance	:53		
Air Conditioning Maintenance	18:00		
Library Development	10:28		
Math 295	16:27		
		97:21	
Use by Departments			
Statistical Service Unit	71:50		
Theoretical and Appl. Mech.	3:32		
Agronomy	9:59		
Civil Engineering	1:33		
Chemistry	11:47		
Coordinated Scientific Lab.	:29		
Agriculture Extension	:43		
Inst. of Labor and Indus. Rela.	:09		
Physics	1:12		
Digital Computer Laboratory	:41		
		101:55	
			199:16

Error Frequency and Analysis

The IBM 650 is normally on from 8 a.m. to 5 p.m. The machine is used for preventive maintenance from 8 a.m. to 12 noon on Wednesdays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for June.

TABLE III'

533	3
Tape Unit	3
Air Conditioning	1
Total	7

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
7/1/59						9:00	650 not turned on.
7/2/59						9:00	
7/6/59	5:38			3:22			
7/7/59	7:39			1:26	1		Left tape unit failing between high and low speed rewind.
7/8/59	4:11	4:12		:44			
7/9/59	7:58			1:02			
7/10/59	7:02			1:58			
7/13/59	4:03			4:57	1		Air conditioning turned off sometime during weekend.
7/14/59	5:04			3:56			
7/15/59	3:06	4:12		1:42			
7/16/59	7:11			1:49			
7/17/59	6:32			2:28			
7/20/59	5:39			3:26			
7/21/59	6:00			3:00	1		Left tape unit failed to unload.
7/22/59	5:05	2:00		1:55			
7/23/59	7:07			2:00			
7/24/59	7:29		:02	1:29	1		Left tape unit failure on rewind
7/27/59	7:02		:36	1:22	1		Fuse blown on 533 (probably due to new SSU panel wiring).
7/28/59	8:50			:10			
7/29/59	5:09	3:45	:06		1		Card jam - 533 read feed.
7/30/59	9:40			:04			
7/31/59	8:25		:09	:34	1		Bent connectors on 533.
TOTALS	128:50	14:09	:53	37:24	7	18:00	

PART V

GENERAL LABORATORY INFORMATION

Reports

Report No. 89, "On Shocks Attached to a Wall in a Stationary or Pseudo-Stationary Two-Dimensional Flow," by Y. S. Chow, July 9, 1959.

Personnel

The personnel associated with the department and, hence, the contributors to this report are:

Bahls, James E., Jr. Laboratory Mechanic
Baur, John W., 1/3-time Research Assistant
Blencoe, Robert W., Computer Operator I
Bowes, Mrs. Doris E., 1/2-time Research Assistant
Carter, Clifford E., Electronics Engineer
Clark, Miss Helen B., Secretary
Cummins, Richard L., Research Assistant
Davenport, Mrs. Margery S., Clerk-Stenographer II
Dickman, Kern W., Research Assistant
Ellsworth, Mrs. Jean E., Clerk-Stenographer III
Fileccia, John L., Electronics Technician I
Fosdick, Lloyd D., Res. Asst. Prof. of Physics
Foster, Merlin J., Computer Operator I
Gear, Charles W., Assistant
Gillies, Donald B., Res. Asst. Prof. of Appl. Math.
Gray, Mrs. Mary T., Research Assistant
Gustafson, Ronald A., Electronics Technician I
Huffman, W. Logan, Computer Operator II
Hunt, Miss Rosalie J., Tab. Machine Operator I
Johnson, Noel H., Research Assistant
Kerkering, Thomas E., Sr. Laboratory Mechanic
Krabbe, Shirlie P., Electronics Technician II for Illiac
Kunihiro, Toshiro, Res. Asst.
Leslie, James D., 1/2-time Research Assistant
Lierman, Richard A., Electronics Technician I
Liu, Chao-ning, 3/4-time Research Assistant
Lopeman, Harold E., Electronics Engineer for Illiac
Meagher, R. E., Head of the Laboratory (on leave beg. April 1, 1959)
Metze, Gernot A., Research Associate
Michael, George W., Administrative Assistant
Muerle, John L., 3/4-time Research Assistant

Muller, David E., Res. Assoc. Prof. of Appl. Math.
Murrell, T. A., Assoc. Prof. of Elec. Eng.
Oare, John W., Draftsman
Peek, Levin J., Res. Asst.
Pelg, Edmund, Electronics Technician II
Penhollow, John O., 1/2-time Research Assistant
Poppelbaum, W.J., Res. Asst. Prof. of Elec. Eng.
Raff, Mrs. Murna J., 1/2-time Assistant
Ray, Sylvian R., Research Assistant
Resh, James A., 1/2-time Research Assistant (started July 16)
Richardson, Warren V., Office Machines Tech. I
Rittis, James A., Part-time Draftsman
Rivera, Ralph M., Jr. Laboratory Mechanic
Robertson, James E., Res. Assoc. Prof. of Elec. Eng.
Rudman, Mrs. Linda G., Computer Teletype Operator (on leave beg. June 3)
Russell, Miss Ramona J., Computer Operator II
Saathoff, Norma I., Computer Teletype Operator
Seiden, Miss Esther, Res. Associate
Serio, Frank P., Electronics Technician II
Shannon, Mrs. Katherine K., 1/2-time Research Assistant
Shively, Richard R., 1/2-time Research Assistant
Snyder, James N., Res. Prof. of Physics
Sullivan, John D., Electronics Technician II
Swartwout, Robert E., 3/4-time Research Assistant
Taub, A. H., Res. Prof. of Appl. Math. (Acting Head of the Lab)
Wenta, Joseph V., Sr. Elec. Technician for Illiac
Wheeler, David J., Research Associate Professor
Wiseman, Neil E., Research Assistant
Wong, Alfred Y.F., 1/2-time Research Assistant (started July 1)

Frank, Evelyn, Professor of Math. (working at Chicago campus)

The Department Advisory Committee consists of Professors L. D. Fosdick, D. B. Gillies, D. E. Muller, W. J. Poppelbaum, J. E. Robertson, J. N. Snyder and A. H. Taub.

Physics

UNIVERSITY OF ILLINOIS
GRADUATE COLLEGE
DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM
PART II - MATHEMATICAL METHODS
PART III - ILLIAC USE AND OPERATION
PART IV - IBM 650 USE AND OPERATION
PART V - GENERAL LABORATORY INFORMATION

August, 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

The annual technical progress report was prepared during the month. A summary of that annual report follows:

1. PROCUREMENT OF SUPPLIES

The procurement of items of major importance is discussed in File Number 294. Briefly, quantity shipments of GF-45011 transistors were resumed early in 1959 after a nine-month delay. Negotiations with Transitron for fast recovery diodes led to a sample shipment of 500 S577G diodes in April, 1959. Although an order for 15,000 units has been outstanding since May, 1959, production difficulties have prevented further shipments.

2. BASIC CIRCUITS

2.1 New Circuits

One of the design goals in a voltage amplifying circuit is to maximize the "logical gain" i.e. the ratio between the actual output current of the circuit and the current in the amplifying transistor, the latter being used in a current switching arrangement. It was shown that increasing the collector return voltage from -25v to -50v (i.e. by making the collector load behave like a more perfect constant current sink), the logical gain could be increased by a factor of 2.

Another investigation led to the introduction of integral gate - flipflop complexes: in these the gate is actually a part of the feedback loop of the flipflop. Normally the gate closes this feedback loop, but during gate-in periods it injects an outside setting signal into the loop. These integral flipflop-gate complexes (so-called "F-Elements") are now widely used to replace Eccles-Jordan flipflops with separate AND gates. The principal advantages of F-Elements over the other system are:

1. Very high signal sensitivity ($\pm$.6v)
2. Very high gate-input sensitivity ($\pm$.6v)
3. Fewer parts than a usual flipflop-gate combination.

Work was also done on a true "last moving point" flipflop. In this design a difference amplifier examines the polarity of a resister in the feedback loop and its output gives a positive indication of whether or not the feedback can "hold" the input when the information signal is taken away.

The examination of chains of AND-OR circuits used in selecting gates during the transfer of information between registers led to the design of so-called "selectors". These are essentially contracted forms of "output ANDs" and "input ORs" made possible by the realization that a flipflop only obtains information from one source at a time. With little extra cost such selectors can be modified to give standardized signals at their output, thus allowing for more cascading.

Drivers involving new principles were designed. In particular, emitter-follower inputs with a Zener diode in the emitter were introduced in order to provide dc-level shift without producing a collector delay. Push-pull drivers having paralleled difference amplifiers in the output stage as well as an "inhibit sink" (connected to the supply of the output stage) were introduced. This sink absorbs the current usually switched between the output stages.

2.2 Circuit Theory

A considerable effort was spent to gain some clearer understanding of the large-signal behavior of transistor-diode combinations. In particular, the notion of a so-called "intrinsic time constant" (minority carrier charge in base/forward current) proved quite successful; once this quantity is known for the diodes and the emitter-base diodes of transistors, it becomes possible to calculate to a fair approximation the operation times of the simpler circuits. Experiments proved the usefulness of the intrinsic time constant theory.

Work was also done concerning the relationship between the width of the (current-) hysteresis loop at the input to a flipflop and the loop gain of its feedback circuit. It could be established that the width of the hysteresis loop is proportional to the loop gain minus one.

The investigation of a simplified flipflop model also showed that the gain · band width product of such a circuit is, in a first approximation, independent of the resistor values. Fairly good agreement with experiment was obtained.

2.3 Power Supply Transients and Low Voltage Supplies

The experience gained with the first test unit showed that one of the major problems in designing a large-scale assembly of circuits is the interaction of these circuits via the common supply busses. To eliminate this problem as far as possible, all collector and emitter resistors are to be provided with RC filters of about 1 μs time constant. The fact that now both emitter and collector resistors act practically like constant sources and sinks of current has also somewhat alleviated the problem.

For the low voltages (+2.2v, -3.1v) used for bumping purposes the common-bus interaction is more serious still. Here the large variation in current imposes a rather radical solution: stabistors are used to create the bumping voltages locally from +25v and -50v. It turns out that the very high junction capacitance of stabistors provides a built-in protection against transients.

2.4 Tolerance Analysis

A general program was started to use a computer to synthesize circuits instead of merely analyzing circuits with given components. The goal is to have the machine find values of the "independent variables"; i.e., the resistors such that maximum drift is allowable and that certain speed requirements are satisfied. In a simplified form such a program (Petite Pilot) exists and has proved successful in designing simple circuits.

In the course of development of the synthesizing program (Grand Pilot) it was found necessary to rewrite the nonlinear circuit routine 1206; the new routine (Sir Kittsolver) is easier to handle and also faster.

3. EXPERIMENTS WITH TRANSISTORIZED SHIFT REGISTERS

3.1 Shifting Register Test Unit (8 bits)

In the second half of 1958 a transistorized Shift Test Unit was built so that some experience could be gained in designing, constructing, and operating a unit involving about 450 transistors and 900 diodes. Questions which needed to be answered were, in particular, whether the set of basic circuits considered best at that time was a compatible set, what operational speeds were to be expected when the basic cirucits were interconnected, what reliability of operation could be obtained, whether the method of packaging chosen was acceptable, and what other problems might be expected in a larger unit.

The Shift Register Test Unit consists of:

a) an eight-bit double rank shifting register with gates,

b) an eight-bit toggle switch register,

c) a fast shift counter employing separate borrow storage,

d) an auxiliary counter which sequences through six states interpreted as 0,1,2,5,6,7, and

e) a speed-independent control.

In operation, an eight-bit number, set up in the toggle switch register, is gated by a push button to the shift register. At the same time, the control is set to the proper initial state. The unit then proceeds through the following sequence of operations automatically: A number j is transferred from the auxiliary counter to the shift counter and j circular left shifts are executed. The number j is again transferred to the shift counter and j circular right shifts are executed. The contents of shift register and toggle switch register are then compared. If no error has occurred, a new value j is formed by a count in the auxiliary counter and the process continues automatically.

Several important facts were learned during the initial testing stage. Some basic circuits had to be modified to furnish higher outputs in order to yield higher operation speeds. It was also found that more information about the behavior of a circuit is needed by the logical designer. The method of packaging was found to be unsatisfactory. Components were inaccessible. Voltage and signal pins were adjacent, thus inviting accidental shorting with catastrophic consequences. Voltage busses ran horizontally on the back of the unit, vertically within chassis. Thus,

suppression of noise on the busses, sometimes as high as 15 per cent, required extensive bypassing outside and inside the chassis.

After these initial adjustments, the unit ran with a basic shift time of 540 mμs. This speed, slower than expected, could be explained by the long chain of control operations. Several modifications of the control shortened that chain and reduced the shift time to 235 mμs. Of course, some of the speed-independent checks had to be weakened in the process.

Error-free runs of 188.0, 387.8, 199.0, 657.0, and 279.4 hours were logged. In each case, the run was terminated by a comparison failure which normally could be traced to a particular transistor or diode. Other marginal components found while checking were, of course, also replaced at that time.

Successive error-free runs of 386.6, 67.1, 547.6, and 343.2 hours were terminated by human intervention. Thus it could be said that the unit ran for more than 1,000 hours without making an error.

3.2 Shifting Register Test Unit (52 bits)

A second test unit has been designed to test the improved set of basic circuits and other new ideas developed during the last twelve months. The second test unit consists of a 52-bit double rank shifting register (52 bits being the word length in the new computer), and two alternate controls. The first control is speed-independent, the second is as fast as possible.

4. DESIGN OF THE ARITHMETIC UNIT

The basic design of the arithmetic unit has been completed and it differs from that described in Report 80 for two reasons. The first is that the work of the circuits group during the year drastically altered the merits of different designs of arithmetic units. The second is that the work of the logical designers resulted in an arithmetic unit with a different emphasis on some of the operations provided. In particular it was decided that the arithmetic unit would be designed primarily for floating point operations, and that the arithmetic unit itself was to furnish results to double precision.

The circuits developed which influenced the design of the arithmetic unit were primarily the selectors and the diode matrix logic. These two developments enabled an adder and selector to be placed in series without the use of slower restoring circuitry. Using these circuits, the arithmetic unit has been designed with two pseudo-adders, with the consequence that the number of steps in most operations has been halved. A diagram of the arithmetic unit is shown on the following page.

The operand is normally placed in register M, while registers A and Q together with registers S and R form a double-length shifting register. A single operation consists of adding one of the multiples +2, +1, 0, -2, -1, of M to A and placing the shifted result into S. The shift may be one or two base-four places either to the left or right. Normally at the same time register Q is shifted into R. The use of the second adder enables a similar operation to take place as S, R is transferred to A, Q.

Multiplication will be performed on a base-four basis with shortcuts as described in Report 80. On the average, the number of steps will be twenty for a 45-digit number. Division will be performed using the method described in Report 82.* The number of steps required will be about twenty-six.

Floating point addition is performed in different ways according to the difference in exponents of the operand and accumulator. Basically, however, either the accumulator will be shifted right and the operand added, or else the accumulator will be cyclically shifted left, the operand added and the result cyclically right shifted. The procedures enable the accumulator to remain double precision.

4.1 Present Status

The arithmetic unit has been designed on a block basis and the special end connections worked out on a feasibility basis. The pseudo-base four-adders have been logically redesigned and the older "carry assimilator" has been replaced by a "carry generator" the output of which is connected to the pseudo-adder. A more detailed exposition of the arithmetic unit is given in Report 92.

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* Also IRE Transactions on Electronic Computers, Vol EC-7, No 3, September, 1958

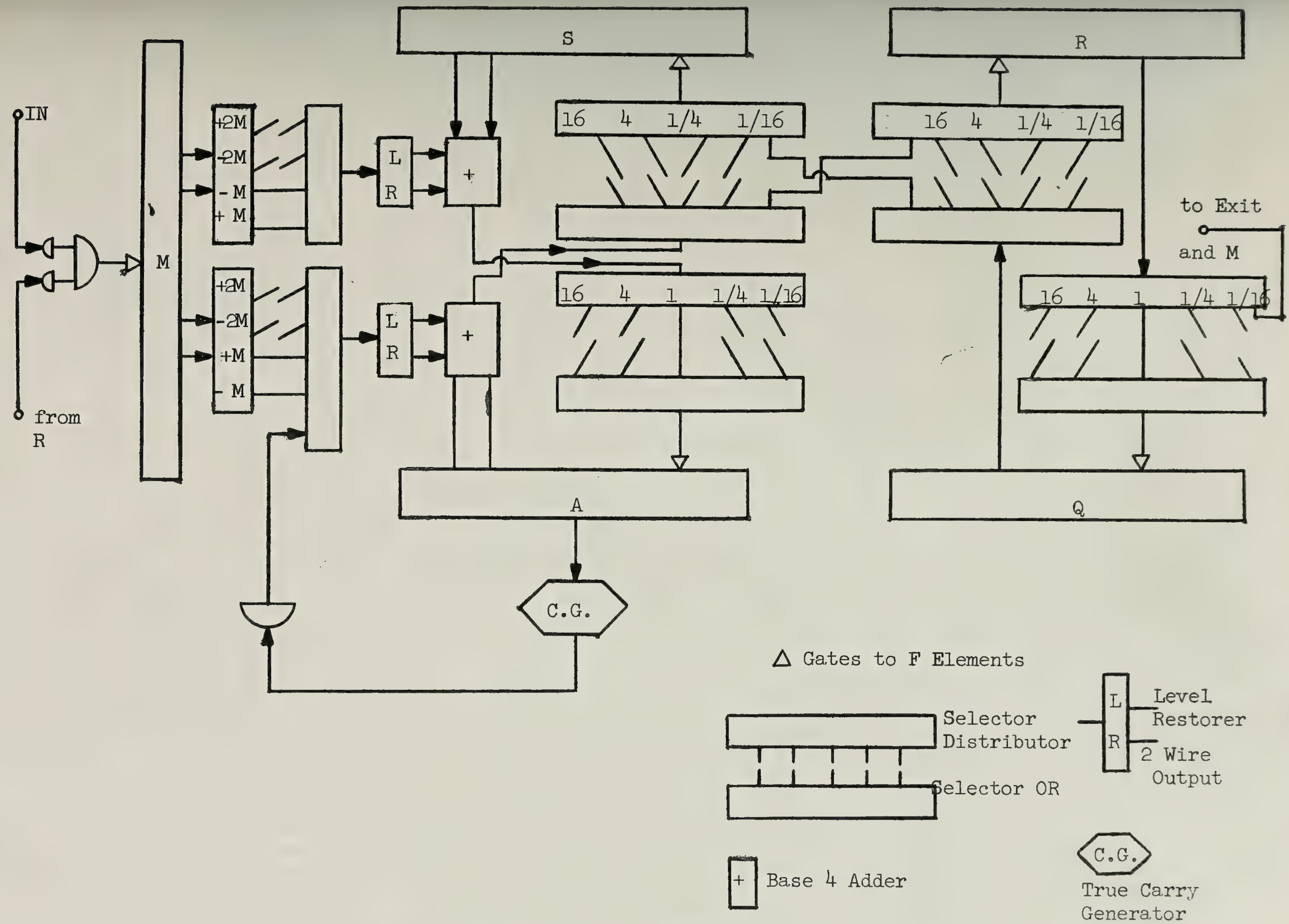

Figure 1

Logical Cross-Section of the Main Arithmetic Unit

5. GENERAL ORGANIZATION

During the month a design study was completed, and is described in detail in DCL Report No. 93. The purpose of this study was to attempt to produce a simpler control for a computer utilizing 17-bit control groups. This type of computer would have the advantage that a large random-access memory could be more readily incorporated. It was decided that the design obtained was not simpler. However it is summarized here because of some interesting counting techniques used, and also because 1, 2, 3, 4, 8 below have been incorporated, and 5 has been incorporated with slight modifications into the 13-bit design previously described.

1. The word-length has been reduced from 53 to 52 bits: a floating point number consists of a 45-bit fraction and a 7-bit base 4 exponent.
2. The effective word-length for fixed point arithmetic is 45 bits. The exponent is made identically zero for all fixed-point words in the memory.
3. The arithmetic unit has been evolved to be especially effective at floating point arithmetic, particularly addition, which is the most complicated floating point order. After an addition, the accumulator holds the correct sum to double precision accuracy, and provision is made to do multiple precision arithmetic quickly.
4. The core memory now consists of 2 independent 4096 word memories which can operate simultaneously. This increases by about 2/3 the rate at which random locations can be addressed in the memory.
5. The fast access (flow gating) memory has been increased to 16 addressable registers: 4 instruction buffers, 4 data buffers (for both reading and writing) and 8 general-purpose registers which can be used either for temporary storage or for the storage of modifiers (b-lines), 3 to a word. Because of duty-cycle considerations, the flow-gating memory will probably be split into 2 parts--one holding instructions, and the other holding modifiers.

6. The length of a control group has been increased to 17 bits. In the case of a short instruction or the first control group of a long instruction, the first 8 bits represent the function to be performed (increased from 7 to 8 bits) and the remaining 9 bits define how the address or operand is to be formed in the following way: If the first bit is zero, the remaining bits are split 2 + 6 for category + address. In this case, the $2^2 = 4$ categories for the address are:

   a) fixed address in the core memory
   b) core memory address relative to the control counter,
   c) the address is to be taken as an integer operand,
   d) the address refers to a fast access transistor register.

   On the other hand, if the first bit is one, the remaining bits are split 3 + 5 for category + modifier address. In this case the $2^3 = 8$ categories are:

   a) the modifier contains the core address,
   b) after use as the core address, the modifier contents is increased by 1,
   c) after use as the core address, the modifier contents is decreased by 1,
   d) after use as the core address, the modifier contents is increased by the contents of the next higher numbered modifier,
   e) (long instruction) the core address is the sum of the modifier and the next control group,
   f) used for double modification: a core address is the sum of any pair of the first 8 modifiers,
   g) spare

   This system of addressing reduces the frequency of long instructions, and largely offsets the fact that the number of control groups per word has been reduced from 4 to 3. Also the address length, 17 bits, provides greater flexibility.

7. Words are placed in the instruction buffers in the same position, modulo 4 as they occupy in the core memory. A record is kept of the significance of each word relative to the control counter. Loops of 4 words or less, whether simple or highly branching, are performed without any unnecessary instruction reads from the core memory.
8. Data buffer registers are used in serial order to hold operands pre-fetched from a core memory, or to hold words to be stored until the memory is ready to accept them. An operand may be referred to several times in this buffer memory since the 4 latest used operands are always available.

6. CORE MEMORY

Since the beginning of this reporting period, several memory components have been received and used in experimental work. The major items are one complete (64-word) core plane, 12,288 storage cores which are wired to simulate three adjacent bits of 2,048 words, and a pre-production lot of Type 2N1072 transistors.

On the basis of experimental work with the above items and other auxiliary equipment, various changes in the original detailed organization of the memory have been found necessary. In particular, the number of wires in the digit-sense group was decreased from 3 to 1 due to oscillatory effects of the larger number and, less important, due to the longer transmission times associated with the 3 wire group. This change has a considerable effect upon digit drivers and sense amplifiers and alters the characteristic impedance of the digit lines so that matching is more difficult.

It was also found that the length of the digit wire must be shorter (by a factor of 4) than was originally planned in order to reduce mutual interference ("cross-talk") of sense signals.

More specifically, it appears that the digit sense wires must be sufficiently short that they may be considered as lumped, rather than distributed, circuit elements relative to the rise time of the sense signal in order that unresolvable interferences should not arise.

A suitable transistor for driving cores (the 2N1072) became available. The system was altered to take advantage of this by reducing the great bulk of vacuum tube drivers (it had been necessary to use large vacuum tubes because of the power dissipation problems). The adaptation to transistors required that the X and Y lines be divided into shorter lengths which results in the magnetic switches being arranged in groups of 1024 (32 x 32). The switches also had to be redesigned for best adaptation to the transistors.

After the sectioning of the various parts of the memory was found to be an engineering necessity (as described above), it was seen that the further separation of the 8192 word memory into two 4096-word memories could be achieved at only a small additional cost (about 10 per cent). This separation was considered to be worth while in terms of the over-all computer organization.

The memory design now assumed would have the following properties and statistics:

General:

1. Word arrangement
2. Two cores per bit
3. Two separate 4096-word sections
4. 52-bit words (+ 2 bits for strobe derivation and parity checking)
5. Magnetic-switch-driven words
6. Cycle time $\leq 2\ \mu s$

Digit Lines, Drivers, and Sense Amplifiers:

1. Each digit-sense line serves one bit of 2048 words
2. 416 D and D_1 drivers (+4 for Strobe) at 520 ma $\pm$ 13.5 per cent, and 58-100 mμs rise time
3. 208 Sense Pre-amplifiers (+4 for Strobe)
4. 104 Sense Amplifiers (+2 for Strobe)

Magnetic Switches and X-Y Drivers:

Switch: 4 windings as follows:

$N_x = 2$ turns $\qquad I_x^{(norm)} = 840$ ma

$N_y = 2$ turns $\qquad I_y^{(norm)} = 840$ ma

N_B = 1 turn $\qquad I_B^{(norm)} = 1.45$ a

N_W = 1 turn $\qquad I_W^{(norm\ output)} = .85$ a

<u>X and Y Drivers</u>:

1. Each drives 32 switch primaries (4.5 μh) in series.
2. 512 total required
3. Output characteristics:

   I = 840 ma ± 13.5 per cent

   Rise Time = 50 - 100 mμs

   Delay from input to output = 30-80 mμs

Although some details have not been thoroughly tested yet, it is felt that the present status of the design and of experimental information is adequate to extrapolate reliably to the following statements: The present design is definitely practical; the cycle time will be no greater than 2 μs, with times of 1.6 ± .1 μs being likely.

PART II

MATHEMATICAL METHODS

1. A New Class of Continued Fraction Expansions for the Ratios of Heine Functions III (Supported in part by the Office of Naval Research under Contract Nonr-1834 (27).)

The study of new continued fraction expansions for the ratios of Heine functions is continued here. A type of continued fraction is identified with that for the ratio of contiguous Heine functions. Functional relations between the ratio of Heine functions are developed, as well as recurrence formulas for the approximants.

(E. Frank)

2. Finite Projective Planes (Supported in part by the Office of Naval Research under Contract Nonr-1834 (27).)

The Illiac was used in order to investigate the existence of a finite projective plane with 11 points on a line. The method of investigation was based on the fact that if such a plane exists then there exists a set of points, no three on one line, called henceforth basis, such that any other point of the plane lies on a line connecting two points of the basis.

It is easy to show that a basis must consist of at least 6 points. On the other hand the assumption that six points could form a basis induces some symmetries which were used for the construction. One of these symmetries is that every quadrangle formed by four points of the basis has to have collinear diagonals. This gives 15 lines which are arbitrary up to notation. Some additional symmetries give 8 more lines arbitrary up to notation. The Illiac was used in order to construct more lines making use of further symmetries. The number of possibilities for the first group turned out to be too large to look at. Therefore the Illiac was stopped and some of the possibilities obtained were used to proceed with the construction. Few minutes of computations of the Illiac showed that each of the first group chosen allowed for at most four possibilities for the second group. There were cases is which there was none or at most one candidate for the second group of lines. None of the second group allowed for further construction. Since then there appears to be a more

hopeful possibility. The assumption that the basis may consist of the maximum number of points, namely 12, induces also considerable symmetries. Here one can write out 21 lines arbitrary up to notation. This method resembles the method of construction used by other mathematicians. On the other hand, the assumption of the existence of a basis consisting of 12 points seems to reduce the number of possibilities considerably. By trial and error 14 more lines were constructed about which however it can be shown that they could not form a part of a geometry. If with the help of a computer one could construct at least 40 lines, then this would prove the existence of two orthogonal latin squares which are different than the one found by Parker and Bose since they would not be a composition of squares of lower order.

(Esther Seiden)

PART III
ILLIAC USE AND OPERATION

Illiac Usage

During the month of August specifications were presented for 15 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1473 T. Numbers followed by T are for theses.

1473 T Electrical Engineering. LP Antenna Impedance. This program solves for the input current to the elements of an antenna array when the impedance matrix of the antenna is known, and the characteristics of the connecting transmission line are specified. This is thus a circuit problem. The computer performs routine matrix operations in complex number floating point arithmetic. The bulk of the calculation solves the matrix equation

$$Ax = b \ .$$

This is accomplished using the Schmidt orthogonalization process for a set of vectors, rather than the more standard upper triangularization and back substitution method.

1474 Psychology. Prediction of Psychotherapy. As part of an extensive psychological investigation into the nature of psychotherapy, the relationships between a variety of objective measures of "personality" and several judgments of improvement are being investigated. Correlations for several sets of measures are needed.

1475 T Education. Factors Associated with Acceptance of the School Lunch Program. The National School Lunch Program is widespread throughout the United States today. Its growth has been phenomenal during the last fifteen years and is continuing unabated. It has become an integral part of many schools and is regarded as one of the ways in which the health and well-being of the nation's youth may be improved.

During the 1957-58 school year approximately two billion school lunches were served to 11.5 million children in more than 60,000 participating schools. The United States Department of Agriculture reported that during March 1957 one-half of the public elementary and secondary schools participated in the National School Lunch Program. However, although approximately two-thirds of the 33 million

pupils were enrolled in these schools, only about 45 percent or 10 million of the pupils in these participating schools ate the school lunch provided for them.

Educators and administrators who work with the school lunch program are aware that many of the children who do not have an adequate noon meal could be benefited by becoming participants in the program. They are also conscious of the fact that participation by students in the lunch program varies from school to school and are concerned with the causes of this variation. Although many studies have been made about the nutritional and managerial aspects of the school lunch program, little has been done to find out why students do or do not eat the school lunch.

This study is an attempt to determine some of the factors that are associated with a high or a low degree of participation, how the students feel about the school lunch program, and the degree of relationship between the students' attitudes and some of the factors that determine those attitudes. It is hoped that a knowledge of some of these factors and the relationships existing between them will be of benefit in improving the school lunch program and thus the health and well-being of the nation's youth.

1476 Electrical Engineering. Magnetic Parameters of Satellite Ray Path. This program is designed to calculate the component of the earth's magnetic field along a ray path of a satellite. A spherical harmonic series up to sixth order is used for this calculation.

1477 Psychology. Parent-Child Interaction. The present study is intended to cover two areas: (1) analysis of ratings made from two hour interviews of 88 mothers and 88 fathers, and (2) integration of findings from studies by Becker, Peterson, Hellmer, and Shoemaker.

1. Analysis of interview data will require the following procedures:
    - (a) Computation of rating reliabilities (two raters evaluated each interview).
    - (b) Computation of means and sigmas by raters to permit evaluation of rater biases.
    - (c) Possible need to convert to standard scores by raters. This decision must await inspection of (b) above.
    - (d) After eliminating unreliable scales, interview ratings will be factor analyzed and factor scores will be computed.

2. Integration of findings will involve taking factor scores from 4 previous separate analyses and intercorrelating them. Because of the number of variables involved, this will possibly necessitate two matrices approaching 100 variables each. Because of the size of the matrices, it may be necessary to factor them to provide an easier way of comprehending the relationships involved.

Illiac programs are available for all major computational steps desired.

1478 Digital Computer Laboratory. Exploding Gas Column. The motion of a gas out of a cylindrical column is to be found in the case where the gas is initially at rest in equilibrium and is then subjected to a very intense heat input inside the cylindrical region, the heat input starting at one end of the column and progressing along the column as the gas blows out.

The problem will be solved by numerical integration of the hydrodynamical differential equations.

1479 T Physics. Analysis of Diffusion Data. The program described under Problem Number 664 is to be used for the analysis of experimental data on the diffusion of chlorine in sodium chloride.

1480 Electrical Engineering. Coax-Radial-Line Junction. In coupling electromagnetic energy to space a junction is often made between a coaxial cable and a radial transmission line. Such a junction scatters the incident electromagnetic wave in a way which depends upon the dimensions of the junction as compared to the wavelength.

The scattering can be computed from an equivalent circuit for the junction. This research problem is the determination, analytically and numerically, of the parameters of the equivalent circuit.

Stationary expressions have been derived for the input admittance seen in the coaxial cable when the radial line is terminated in reflecting and non-reflecting ways. These expressions contain infinite series which are slowly converging for the values of parameters of interest. By using extrapolation and the Illiac, computation of the series and the other parts of the necessary expressions for the several parameters necessary to describe the junction, become feasible.

1481 Animal Science. Comparison of Quantitive and Qualitative Measures of Carcass Value. A comparison of numerous qualitative and quantitive measures of meat animal carcass value will be made in order to derive the most suitable measures.

The method of least squares will be used.

1482 Mathematics. Neyman Shortest Confidence Intervals. Neyman shortest unbiased confidence intervals for Binomial and Poisson parameters are to be computed. The calculation consists of generating pairs of numbers which depend discontinuously on a parameter. At a discontinuity the machine must set in a new constant.

The pairs, γ_0 and γ_1, are given by

$$\gamma_0 = \frac{(n_1 - \lambda)[P(n_0 \leq x \leq n_1 - 1) - \alpha] - n_0\, P(x = n_0) + n_1\, P(x = n_1)}{(n_1 - n_0)\, P(x = n_0)}$$

$$\gamma_1 = \frac{(n_0 - \lambda)[P(n_0 \leq x \leq n_1 - 1) - \alpha] - n_0\, P(x = n_0) + n_1\, P(x = n_1)}{(n_1 - n_0)\, P(x = n_0)}$$

where $P(X = x) = e^{-\lambda} \cdot \lambda^x / x!$; $x = 0, 1, 2$

$$P(n_0 \leq X \leq n_1 - 1) = \sum_{x=n_0}^{n_1-1} e^{-\lambda} \cdot \lambda^x / x! \quad .$$

For given α(first .95, then .99) the set of equations is solved successively for a series of values of λ = .005, etc. Method: use trial values of n_0, n_1; if resulting γ_0, γ_1 are in [0,1] this is the solution. If $\gamma_i > 1$ increase n_i by 1, if $\gamma_i < 0$ decrease n_i by 1. Initial trial values for n_0, n_1 are those for preceding λ values.

The given equations state the Poisson case. The Binomial case is given by an analogous expression.

1483 T Agricultural Economics. Rate of Innovation. The problem is to test the hypothesis that the rate of innovation (that is, the percentage of paddy land brought under new methods of production, called the Japanese Method) is a function of the increase in yield per acre over the years, the difference in cost between the two methods, and the accumulated effect of innovation over past years. The rate of innovation is a dependent variable here and the others are independent variables. The hypothesis will be tested by multiple correlation, simple regression having already been made.

1484 Psychology. Parent-Child Interaction and Child Behavior.

A. Description of the problem: This research is a study of parent-child interaction as measured in a playroom situation. The particular emphasis is on aspects of this interaction that are related to the development of psychologically maladjusted behavior in the child.

B. Mathematical procedures:

1. Measurement of reliability of ratings through linear correlation.
2. Factor analysis of pooled ratings for mother, father, and child separately.
3. Computation of factor scores for all of the above.
4. Integration with other findings, using correlation technique.

C. Standard library routines are available for all necessary operations.

1485 T Education. Concept Teaching Simulation. A study of teacher and learner strategies in concept attainment has been made. For definiteness, the problem may be characterized as follows: the learner is to be taught a concept A which bears the truth-functional relation

$$A = f(B,C,\ldots)$$

to a set of attribute variables B, C, ... The teaching is conducted by presenting to the learner a sequence of positive and negative instances of the concept A. The learner's task is to observe which attribute combinations occur in conjunction with A and which occur in conjunction with A' (the complement of A).

The teacher's task is to choose the instances to be presented to the learner in such a way as to facilitate the learning process -- tailoring the choice to the learner's strategy pattern for constructing a hypothesis about the concept A from the instances given. The teacher wishes, of course, to minimize the complexity of the learner's conjecture and to minimize the number of instances necessary to teach the concept.

The question naturally arises as to whether this process of instance-selection could not be made completely mechanical. In connection with the current interest in automatic or mechanical teaching devices, it is desired to determine whether such a device is technically feasible (even if it proves not to be economically feasible).

It is proposed to use Illiac to simulate such a device. More specifically, Illiac is to be used to demonstrate the feasibility of mechanizing the process. It is not intended at present that extensive production time be used. The primary

purpose is exploratory programming -- to test the feasibility of the mechanization scheme.

In order to avoid the difficulties inherent in operating in real-time, a program has also been written to simulate the behavior of the learner, so that the machine will be communicating, in a sense, with itself rather than a human learner.

1486 Veterinary Pathology and Hygiene. Pathogenesis of Duck Hepatitis. An evaluation of serum components in both normal ducks and in ducks infected with duck hepatitis virus is to be made. The serum measurements involve serum protein changes resulting from age and from disease in ducks.

The statistical analysis will be made by the method of least squares.

1487 T Chemistry. Vibrational Analysis of a Three-Center Model. This program will calculate vibrational frequencies for paired sets of isotopically substituted triatomic molecules. The method includes finding products, inverses, and determinants of 3 x 3 matrices whose elements are simple functions of the input data, and solving 2 quadratic equations.

About 100 sets of input data will be used.

Table I shows the distribution of Illiac machine time for the month of August.

TABLE I

	Hrs:Min	
Regular Maintenance	100:14	
Unscheduled Maintenance	23:14	
Drum Engineering	25:29	
R.A.R.	5:28	
Leapfrog	27:32	
Library Development	:38	
		182:35

(cont'd.)

TABLE I
(cont'd.)

	Hrs:Min
Classes	:23
Agricultural Economics	2:22
Agronomy	:51
Animal Science	5:42
Astronomy (NSFG 5512)	5:40
Astronomy (NONR 1834(22))	2:43
Bureau Educational Research	26:42
Chemistry	51:33
Coordinated Science Laboratory	51:00
Dairy Science	:05
Electrical Engineering (NSFY 32-40-266)	3:38
Electrical Engineering (SC 73163)	:13
Electrical Engineering (NSFG 7421)	:13
Electrical Engineering (AF 6079)	:34
Electrical Engineering	5:06
Education	12:54
Zoology	3:33
Economics (NWFG 7056)	5:48
Economics	:09
Digital Computer Laboratory	33:56
Physics	11:48
Psychology (PH M1041R1)	3:34
Psychology (NONR 1834(11))	:24
Psychology (AF-49-625-331)	10:25
Psychology (PH 1715)	3:14
Psychology (PH 1774)	:04
Psychology (MH 7289)	1:01
Psychology	36:16
Sociology	5:30
College of Medicine	:41
Mathematics	1:21
Theor. and Appl. Math. (ORD 593 I.C.)	2:03
Structural Research (AF 464)	8:57
Structural Research (NSFG 6572)	:57
Structural Research (NONR 1834(03))	:08
Structural Research (AASHO Rd. Test)	3:03
Structural Research	52:38
Sanitary Engineering	:03
State Water Survey (SC 7055)	5:07
State Water Survey	:22
State Geological Survey	:20
Institute of Commercial Research (PH 9067)	3:08
Inst. Research Exceptional Children	:43
Mechanical Engineering (ORD 1980)	:24
Mechanical Engineering (I.B.R.)	:02
Mechanical Engineering	1:08
Mining and Met. Engineering (AF 3789)	:19
Mining and Met. Engineering	:30
Veterinary Physiology	:07

(cont'd.)

TABLE I
(cont'd.)

	Hrs:Min		
Student Counseling	:43		
Physical Education	1:08		
Marketing	:43		
Botany (Eastern Illinois University)	:24		
Bureau of Economic and Business Research	:08		
Michigan State University	2:30		
		372:58	
			555:33

Error Frequency and Analysis

The Illiac is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and Laboratory functions, it is more instructive for an error standpoint to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind a summary table has been prepared, using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:30 - 6:30 period (when the machine is checked), if no errors are to be found, the time is given to the "running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a

later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for August.

TABLE III

Drum	7
Memory	4
Arithmetic	1
Control	4
Reader	1
Punch	1
Unknown	16
Operator	1
Total	35

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
8/3/59	19:00	:00	5:00	0		0	1:00	0
8/4/59	18:59	:01	5:00	1	(1) Drum failure	0	:40	0
8/5/59	17:05	2:05	4:50	1	(1) Drum failure	0	:40	0
8/6/59	19:06	:00	4:54	0		0	1:01	0
8/7/59	20:46	:01	3:13	1	(1) Unknown	0	:40	0
8/10/59	12:41	6:19	5:00	1	(1) Memory error 2^{-6}	0	:40	0
8/11/59	18:58	:00	5:02	0		0	:40	0
8/12/59	18:01	:59	5:00	2	(1) White switch failure (2) Operator error. Tape inside reader	0	:40	0
8/13/59	18:57	:03	5:00	3	(1) Unknown (2) Unknown (3) White switch failure	0	:40	0
8/14/59	17:42	1:14	5:04	3	(1) Drum failure (2) Unknown (3) Memory power failure	0	:59	0
8/17/59	19:17	:01	4:42	1	(1) Drum Failure	0	:40	0
8/18/59	17:17	1:54	4:49	2	(1) Reader "B" failure (2) Arithmetic error	0	:40	0
8/19/59	18:47	:13	5:00	2	(1) Unknown (2) Unknown	0	:40	0
8/20/59	17:52	1:08	5:00	3	(1) Punch "3" error (2) Drum failure (3) Unknown	0	:40	0
8/21/59	19:11	:49	4:00	2	(1) Drum Failure (2) Unknown	0	:46	0
8/24/59	19:00	:00	5:00	0		0	:41	0

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
8/25/59	18:55	:05	5:00	4	(1) Unknown (2) Unknown (3) Unknown (4) Unknown	0	:40	0
8/26/59	17:20	1:40	5:00	4	(1) Memory (2) Control error (3) Control error (4) Unknown	0	1:14	1
8/27/59	18:59	:01	5:00	1	(1) Drum failure	0	:25	0
8/28/59	16:09	3:51	4:00	4	(1) Memory (2) Unknown (3) Unknown (4) Unknown	0	1:02	0
8/31/59	19:00	:00	5:00	0		0	:40	0
TOTALS	383:02	20:24	100:34	35		0	15:48	1

PART IV

IBM 650 USE AND OPERATION

New 650 Codes

During the past two months fourteen new routines were added to the 650 Library.

Y6'-33' Tape Output. This routine transfers information from magnetic tape to either punched cards or printed pages. Tape records may be of variable or fixed length and the actual length of these records need not be known.

(K. E. Shannon)

M2'-34' Floating Point Matrix Inversion or Solution of Simultaneous Linear Equations. This routine inverts a matrix of order n or solves b sets of linear equations with common coefficient matrix, n and b must satisfy the relation $(n+1)(n+b) \leq 1923$. The Gaussian Elimination method is used.

(M. T. Gray)

T5'-35' Fixed Point Arc Sin A.

(M. T. Gray)

Y7'-36' Punch or Print Tape. This routine transfers information from magnetic tape to either punched cards or printed pages. The information will be extracted from a tape starting at record A and extending through record B or N records may be extracted starting at record A. Tape records may be of variable or fixed length and the actual length of the records need not be known.

(K. E. Shannon)

M3'-37' Floating Point Matrix Multiplication Subroutine.

(M. T. Gray)

Y8'-38' Autoset. This routine will set a tape containing records of fixed known length to a predetermined position.

(K. E. Shannon)

R3'-39' <u>Fixed Point Nth Root.</u>

(M. T. Gray)

Y9'-40' <u>Dump I. A. S. and Drum onto Tape.</u> This routine places the contents of the drum and of the immediate access storage onto tape with the loss of only the ten words in 1951-1960.

(K. E. Shannon)

Y10'-41' <u>Load I. A. S. and Drum From Tape.</u> This routine will reload the drum and the immediate access storage from a tape prepared by Y9'-40'.

(K. E. Shannon)

Y11'-42' <u>Determine Length of a Reel of Tape.</u> This routine will read a tape and determine its length in feet. The contents of the tape are lost.

(K. E. Shannon)

Y12'-43' <u>Measure off a Predetermined Length of Tape.</u>

(K. E. Shannon)

X7'-44' <u>Checkmate; (Test for duplicate use of drum locations by SOAP).</u> This routine loads SOAP output cards (one-per-card load cards) and tests for duplicate use of drum locations. If a word is assigned a space already occupied, then the loading program will stop with: program register - 01 XXXX 1961; lower accumulator - contents of XXXX, where XXXX is the doubly assigned drum location.

(K. E. Shannon)

R4'-45' <u>Floating Point Nth Root.</u>

(M. T. Gray)

R5'-46' <u>Floating Point Cube Root of X.</u>

(M. T. Gray)

IBM 650 Usage

During the month of August specifications were presented for 7 new problems. Numbers followed by T are for theses.

37' Statistical Service Unit. Correlation of an M x N Matrix. This program will compute correlations, standard deviations, corrected sums of squares, corrected sums of cross products, regressions, and averages of "M" data against "N" variables, where "M" is part of "N".

The number of variables to be considered, "M", is limited to 10, and the total number of variables to be processed, "N", is limited to 120. Thus, maximum size of the matrix is 10 x 120.

Formulas used:

Average: $$\bar{x} = \frac{\sum x}{N}$$

Corrected Sums of Squares: $$\sum' x^2 = \sum x^2 - \frac{(\sum x)^2}{N}$$

Corrected Sum of Cross Prod.: $$\sum' xy = \sum xy - \frac{(\sum x)(\sum y)}{N}$$

Regression formula: $$b_{xy} = \sqrt{\frac{\sum' xy}{\sum' x^2}} \quad ; \quad b_{yx} = \sqrt{\frac{\sum' yx}{\sum' y^2}}$$

Correlation: $$r = \sqrt{b_{xy}\, b_{yx}}$$

Standard Deviation: $$S.D._x = \sqrt{\frac{\sum' x^2}{N-1}} \quad ; \quad S.D._y = \sqrt{\frac{\sum' y^2}{N-1}}$$

Where: N = Sample size

x = Any one "M" element

y = Any one "N" element

Results can be printed, punched, or both.

38' Psychology. Computation of Reliabilities. The problem is to compute the reliabilities by means of Product Moment Correlations, means, and Standard Deviations of a number of ratings. The ratings have been made on the basis of ethnographic material from a world-wide sample of primitive societies. The ratings concern various types of aggression, beliefs about the causes of crop and hunting failures, types of religious practices, and the relative status of men and women in the tribe.

39' T Institute of Labor and Industrial Relations. Predicting Academic Success In Labor and Industrial Relations. The problem is to predict academic grade point average in Master's degree program at the Institute of Labor Relations. Predictor variables are age, type of undergraduate school (size, legal control, reputation), Miller Analogies Test, Ohio State Psychological Test and 48 occupational scores on the Strong Vocational Interest test. Total sample size is 137. All predictors will be correlated against graduate grade-point average and correlated against each other.

40' Statistical Service Unit. 2-Digit Numbers Frequency Counting. This routine is to be part of the Statistical Service Unit's library. It recognizes 36 2-digit fields per card, and counts the frequency of numbers ranging from "0" to and including "99", per 2-digit field. It outputs the frequency distribution per field in the form of percents and counts. Output is all in printed form.

41' T Education and Statistical Service Unit. Factors Associated with Acceptance of the School Lunch Program. The National School Lunch Program is widespread throughout the United States today. During the 1957-58 school year approximately two billion school lunches were served to 11.5 million children in more than 60,000 participating schools. The United States Department of Agriculture reported that during March 1957, one-half of the public elementary and secondary schools in the U. S. participated in the National School Lunch Program. However, although approximately two-thirds of the 33 million pupils were enrolled in these schools, only about 45 percent or 10 million pupils in these participating schools ate the school lunch provided for them.

Educators and administrators who work with the school lunch program are aware that many of the children who do not have an adequate noon meal could be benefited by becoming participants in the program. They are also conscious of the fact that participation by pupils in the lunch program varies from school to school and are concerned with the causes of this variation. Although many studies have been made about the nutritional and managerial aspects of the program, little has been done to find out why students do or do not eat the school lunch.

This study is an attempt to determine some of the factors that are associated with a high or low degree of participation, how the pupils feel about

the program and the degree of relationship between the students' attitudes and some of the factors that may determine those attitudes. Identification of some of these factors and the relationships existing between them should be of help in improving the health and well-being of the nation's youth.

In this study, an interview schedule for the administrator was used by the investigator to secure information about the school and its lunch program. A check list was given to over 3,300 pupils in grades 5 through 12 in 58 schools to secure information about these students and their attitudes. The data obtained were coded and put on IBM cards. From this data, the IBM 650 may be used to obtain correlation coefficients between the various factors that are associated with pupil participation in the school lunch program and with their attitudes toward it.

42' T Civil Engineering. Buckling of Cylinder. The 650 will be used in floating point to determine the minimum value of a function of two variable integers which each have a range between 1-100 for the given input data. Therefore the machine must take every possible combination of these integers to determine the minimum. Once this value is obtained some simple algebraic manipulations will be made to present the results in a useful form.

Example:

$$\text{Function} = F = \frac{1}{\lambda}\left\{\frac{g(ab-de)+h(cd-af)}{ac-bf} + j\right\}$$

where a typical term a might be

$$a = \left(\frac{m}{n}\right)\alpha\beta\gamma + \frac{\theta\phi}{\delta}\left(\frac{m}{n}\right)^2$$

where α, β, γ, θ, ϕ, δ are input parameters,

m, n = integer of range 1-100.

43' Agricultural Education. SCAT Test vs. College Grades. Pearson product moment correlation will be carried out for 840 students in order to determine the relationship between college grades, high school rank and aptitude score.

Table I' shows the distribution of the IBM 650 machine time for the month of August.

TABLE I'

	Hrs:Min		
Regular Maintenance	12:39		
Unscheduled Maintenance	13:02		
Painting	17:00		
Library Development	4:33		
Wasted	31:30		
		78:44	
Use by Departments			
Mathematics 295	4:52		
Agricultural Extension	:44		
Agronomy	10:55		
Chemistry	2:56		
Digital Computer Laboratory	2:30		
Physics	2:46		
Statistical Service Unit	73:43		
Structural Research	7:24		
Theor. and Appl. Mechanics	5:34		
		111:24	
			190:08

Error Frequency and Analysis

The IBM 650 is normally on from 8 a.m. to 5 p.m. The machine is used for preventive maintenance from 8 a.m. to 12 noon on Wednesdays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for August.

TABLE III'

Broken wire	4
Tube failure in 650 console	1
Fuse in 407	1
Engineering switch set wrong	1
Circuit breaker dirty in 533	1
Belt on drum broke	1
Unknown	1
Total	10

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	PAINT-ING	TYPES OF FAILURES CAUSING REPAIR TIME
8/3/59	8:10			:50	0		
8/4/59	8:17			:43	0		
8/5/59	3:38	3:42	1:10	:30	2		These errors due to a broken wire found on August 7th
8/6/59	2:50		5:19	:51	1		
8/7/59	6:46		2:04	:16	1		
8/10/59						9:00	
8/11/59	:50			:10		8:00	
8/12/59	6:03	1:23		1:34	0		
8/13/59	7:48			1:12	0		
8/14/59	6:05		1:56	:59	1		Tube failure in the 650 console
8/17/59	3:51			5:09	1		Fuse blew in 407 - no down time for 650
8/18/59	6:57			2:03	0		
8/19/59	3:09	4:00		1:51	2		(1) Missing bits in distributor (2) Engineering switches in contol unit set wrong
8/20/59	8:11			:49	0		
8/21/59	8:51			:24	0		
8/24/59	8:58			:40	0		
8/25/59	6:52		1:03	1:05	1		Circuit breaker in 533 dirty
8/26/59	3:17	3:34	1:30	:44	1		Belt on drum broke
8/27/59	8:49			:15	0		
8/28/59	5:05			3:55	0		
8/31/59	1:30			7:30	0		
TOTALS	115:57	12:39	13:02	31:30	10	17:00	

PART V

GENERAL LABORATORY INFORMATION

Reports

No. 90, "Circuit Design for the New Illinois Computer", by W. J. Poppelbaum and N. E. Wiseman, August 20, 1959.

No. 91, "Design of the Core Storage Unit", by S. R. Ray, August 20, 1959.

No. 92, "The Arithmetic Unit" by David J. Wheeler, August 21, 1959.

No. 93, "Organization of a Very High-Speed Computer", by D. B. Gillies, August 22, 1959.

Personnel

The personnel associated with the department and, hence, the contributors to this report are:

Bahls, James E., Jr. Laboratory Mechanic
Baur, John W., 1/3-time Research Assistant
Blencoe, Robert W., Computer Opeator I
Bowes, Mrs. Doris E., 1/2-time Research Assistant
Carter, Clifford E., Electronics Engineer
Clark, Miss Helen B., Secretary
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Meagher, R. E., Head of the Laboratory (on leave beg. April 1, 1959)
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Rittis, James A., Draftsman
Rivera, Ralph M., Jr. Laboratory Mechanic
Robertson, James E., Res. Assoc. Prof. of Elec. Eng.
Rudman, Mrs. Linda G., Computer Teletype Operator (on leave)
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The Department Advisory Committee consists of Professors L. D. Fosdick, D. B. Gillies, D. E. Muller, W. J. Poppelbaum, J. E. Robertson, J. N. Snyder and A. H. Taub.

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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - MATHEMATICAL METHODS

PART III - ILLIAC USE AND OPERATION

PART IV - IBM 650 USE AND OPERATION

PART V - GENERAL LABORATORY INFORMATION

September, 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Shifting Register Test Unit

The unit stopped on September 14th because the pilot lamp in the dc turn-on box had burned out.* Difficulties in restarting were found to be due to three transistors which were then out-of-tolerance. This again seems to indicate that transistors tend to deteriorate when the unit is permitted to "cool down". After two comparison failures on September 19th and 22nd which could not be traced the unit continued to run without error.

(H. E. Lopeman and
C. E. Carter)

2. 52 Bit Shifting Register

Circuit drawings and component layout drawings for the drivers, the clock control, the 2-bit worst case chassis, as well as the main frame layout and wiring diagrams were finished. These, together with the drawings for the repetitive 4-bit chassis completed last month, now fully describe the synchronously controlled version of Test Unit II.

(H. E. Lopeman and
C. E. Carter)

The speed-independent control, which is to be physically interchangeable with the clock control, is being revised. A more accurate description of the operation of the currently available F and C elements is used in the design. In this description, the "1" output is considered approximately "last moving point". If needed, a "0" output is obtained by a NOT circuit from the "1" output rather than directly, since the direct "0" output changes before the feedback loop is closed.

(R. E. Swartwout)

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* Life of these bulbs seems to be less than 4,000 hours.

3. Last Moving Point

Circuits

The basic circuit drawings are being brought up to date to include information such as voltages at critical nodes (for each possible state of the circuit) and detailed power requirements.

An earlier last-moving-point (l.m.p.) flipflop design is being modified to use standard voltages. Various gating schemes leading to l.m.p. memory elements such as a l.m.p. C-element are being investigated.

(N. H. Johnson)

4. Arithmetic Unit Design

A logical diagram of a typical two bit cross section of the MAU (main arithmetic unit) was completed. The data paths are in accordance with those established by D. J. Wheeler in Report No. 92. The diagram incorporates the symbolism and design rules as set forth by Neil E. Wiseman and W. J. Poppelbaum in File No. 288. This cross sectional diagram can only be considered typical over bit positions 7 through 40 in A and S, and 5 through 40 in Q and R.

On the basis of this diagram an estimate was made of the total component and power requirements for the registers with associated gates, selectors, level restorers, and base 4 pseudo-adders.

(J. O. Penhollow)

Exponent Arithmetic Unit (EAU)

A study of the compatibility of the latest instruction code definitions with the tentative description of EAU given in Report 92 is in progress. A design proposal for the Shift Counter, adhering as closely as possible to speed independence, is completed.

(R. R. Shively)

5. Core Storage Unit

The configuration of the amplifier section of the sense amplifier was designed and tested with favorable results. The detailed design is being pursued.

Further tests of the effect of switch core half-select currents on the states of the storage cores were made. These disturbances tend to increase, rather than decrease, the amplitude of the sense signal produced when full read-out exists.

(S. R. Ray)

A driver having its load in the emitter of the high power transistor and having feedback to regulate the load current was designed and built. The transistor lineup from input to output is GF-45011, H4A, 2N546, and ST401. The H4A had such a slow risetime even as an emitter follower that no further tests were made on the driver. A much faster replacement for this transistor will have to be found or else the circuit will have to be redesigned using an NPN transistor in place of the PNP H4A.

(J. L. Muerle)

6. Input-Output and Auxiliary Storage

A visit was made to the Ampex Corporation on September 2-September 5 by R. L. Cummins and L. J. Peek to discuss operational and maintenance difficulties with~~out~~ our FR-300 magnetic tape handler. Recent developments in playback electronics were discussed and it appears that Ampex will soon be in a position to supply playback electronics capable of 600 bit/inch operation for determining the program restrictions associated with the tape unit.

A remote control panel is being designed for use with the FR-300. In addition to normal manual operation, provision is made for cyclic FWD-REV operation for determining the program restrictions associated with the tape unit.

(R. L. Cummins)

The design of the test chassis for the tape unit has been completed. It will record the running time of each motor speed (20, 40, 150, and 225 ips.), total A.C. on time, total running time in each direction, and number of operations of each pinch roller actuator.

(L. J. Peek, Jr.)

Preliminary drop-out tests were performed on the FR-300 magnetic type unit. Continuous one's were written on three channels across the tape and the coincidence of two adjacent channels were checked. Tests were performed for densities of 200 bits/inch and 300 bits/inch, both at a tape speed of 150 inches/sec. An average of about 40 errors per pass of a full reel of tape was registered. However, since the coincidence checker registered nothing for the case when drop-

outs occurred in both channels under test, the recorded error number was probably lower than the actual case.

(C. N. Liu)

Preliminary check-out of the ring-counter to be used in checking the drop-out in the Ampex tape unit was started. A few wiring errors or omissions have been found.

(T. C. Piper)

PART II

MATHEMATICAL METHODS

1. Classical Hydrodynamics (Supported in part by the National Science Foundation under Grant G9503)

(Supported in part by the National Science Foundation under Grant G9503)

1.1 Detached Shocks in Non-viscous Flow

The behavior of compressible flow in the neighborhood of the nose of a blunt body in two dimensional stationary flow can be described by the solutions of a set of five nonlinear total differential equations of the first order. These are obtained by expressing the flow variables as power series in R, where R, β are polar coordinates in the s, T plane with the origin at the nose, and then considering the first non-zero terms in the five flow equations. The total differential equations for the higher order terms are first order and linear.

1.2 "Shocks" in Viscous Flow

A study of the nature of the transition zones in viscous flow corresponding to the shock wave and the slip-stream of non-viscous flow suggests that it may be possible to describe the flow variables behind the "shock" or on the trailing edge of the transition zone by the equations:

$$\xi_i = \xi_i^{RH} (\alpha) + kw \ f_i (\alpha) + 0 (w^2)$$

where w is the viscosity, α is the suitably defined angle of the "shock" and k is its derivative with respect to s. $\xi_i^{RH} (\alpha)$ is the usual Rankine Hugoniot solution. Across the "slip-stream" the two usual equations are replaced by

$$[P] + wF (\xi_j, \frac{\partial \xi k}{\partial t}) + 0(w^2) = 0$$

$$wG (\xi_j, \frac{\partial \xi k}{\partial t}) + 0(w^2) = 0$$

and

$$wH (\xi_j, \frac{\partial \xi k}{\xi t}) + 0(w^2) = 0 .$$

If these results are valid approximations, then it can be seen that the limiting case as w tends to zero can give different results from the Rankine Hugoniot theory if kw does not tend to zero due to the boundary conditions.

(C. W. Gear)

PART III

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of September two new routines were added to the Illiac Auxiliary Library.

Aux. P21-268 Data Plotter Output Converter II. Under the control of parameters this routine will convert a data tape output by the standard Illiac printing routines into a tape suitable for input to the data plotter.

(C. Sprankel)

Aux. X15-269 Maximum Speed Sexadecimal Input Preparation for Magnetic Drum and/or Williams Memory. This routine permits loading of the drum and/or Williams memory from the reader at maximum speed. Any information previously assembled on the drum or in the Williams memory is punched out in sexadecimal form in such a manner that the tape (provided with its own bootstrap) can be read in and sum checked at some later time.

(W. Lichtenberger)

Illiac Usage

During the month of September specifications were presented for 17 new specifications. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1488 T. Numbers followed by T are for theses.

1488 T Sociology. Patterns of Inmate Response. The problem is to group questions (55) in terms of common differentiation of 556 subjects. What are some of the common patterns of responses? Which questions can be grouped together? A pattern analysis is used (KSL 294) in which the usual order of persons and responses is reversed.

1489 T Sociology. Subject Similarities. The problem is to group inmates in terms of how they answer questions about prison life and themselves. A pattern analysis is used in the standard way on each of two subsamples of 50 subjects.

Two subsamples are used:

1. To investigate the reliability of the patterns obtained.
2. To compare samples from two different prisons on differences and similarities in patterns of response.

1490 Civil Engineering. Thermal Stresses in Elastic Shells. This is to solve the problem of an elastic shell subject to the transient temperature input associated with high velocity motion through an atmosphere of variable density, although any temperature history input could be used. Two kinds of thin shells are being studied; spherical dome shells and conical shells.

The significance of this analysis lies in the possibility of treating shells under either applied loads or temperature variations by one unified approach.

The method of solution is a finite difference approach, applied successively as time is increased incrementally.

1491 T Economics. Analysis of the Demand for Coffee. The problem consists of estimating price and income elasticities of the demand for coffee in the United States. Yearly data on coffee demand, prices, stocks, and imports to the United States will be used. For the estimation of the demand equation a limited information estimate will be used. No other than standard library routines are involved.

1492 Mechanical Engineering. Nozzle Design for 4" x 4" Blow Down Tunnel. It is intended to design a pair of nozzle blocks for the blow down tunnel in Aerodynamics Laboratory B. The supersonic nozzle profile will be first calculated by the method of characteristics and then corrected for the boundary layer growth along the nozzle. The complicated step-by-step calculations and iterations can easily be handled by Illiac.

The fundamental net calculation has been developed under Problem No. 866 and the general boundary layer calculation has also been developed under

Problem No. 1189. It is hoped to adapt and modify the codes from Problem Numbers 866 and 1189 so that the final nozzle profile for a certain supersonic test Mach number can be produced.

1493 Botany - Eastern Illinois University. Analysis of Tree Growth. This problem is a continuation of an earlier problem, Problem No. 1267, in which daily tree growth measurements are analyzed using the standard program, K 16. The best fitting equation for predicting daily growth is being obtained by attempting multiple correlation using different combinations of factors on different species of trees and for different periods of the season.

Part of this newly submitted data are measurements of growth occurring before leaf enlargement during 1958 and 1959, a period which differs markedly from the later growing season. Part of the new data are yearly growth ring measurements from 1901-1951. These are to be analyzed in terms of values ascertained from monthly weather bureau records. This second approach using yearly rather than daily growth measurements was conceived because of an evident influence of the previous season upon the growth of trees. It is hoped that by combining an analysis of daily growth during a given year with an analysis of seasonal growth during a number of years it will be possible to evaluate both the immediate and long-range effects of our weather upon tree growth.

1494 Psychology. Situation-Response Analysis of Anxiety Behavior. This study differs from other studies of anxiety, even though it is based on an inventory, because both situations and responses are specified in the structure of the inventory. Four groups of subjects, a total of 348, were presented with the description of some situation and asked to say whether and to what degree he would show each of a sample of emotional responses.

The K-8 routine is to be used to compute Product Moment Correlations, Means and Standard Deviations for each of the responses for the four groups. A factor analysis for each of the groups is to be computed using KSL-1.90 on the Correlation Matrices.

1495 Animal Science. Potassium Requirement for Baby Pigs. This research is intended to ascertain the amount of potassium required for optimal growth by the baby pig. The mathematical method is the method of least squares.

1496 T Veterinary Medicine and Physiology. Strontium and Calcium Metabolism. The replacement of calcium in the diet of young pigs by strontium is being compared to controls receiving calcium, negative controls receiving neither calcium nor strotium, and pigs receiving both ions. Illiac is being used to analyze the variance between the treatment groups for the various criterions used, i.e. weight gain, bone calcium, bone strontium, etc.

1497 Agricultural Economics. A Game Theoretic Model for Cattle Feeding. The feeder cattle enterprise is viewed as a game against nature with nature's choices assumed to be restricted to the price-cost situations generated in the last ten years. The farmer's choices consist of six different feeding systems (or linear combinations of these). Four different situations are considered:

1. Payoff matrix in terms of returns per $100 feed fed.
   a. Maximize the minimum return.
   b. Minimize the maximum loss or "regret".
2. Payoff matrix in terms of returns per animal.
   a. Maximize the minimum return.
   b. Minimize the maximum loss or "regret".

This problem may be set up as a linear programming problem with straightforward use of the library routine M15-183.

1498 Physics. Resonance Absorption in U-H. This is a revision of old Problem Number 1289 for Uranium-Hydrogen mixtures. Problem Number 1289 treated mixtures of uranium and moderators with mass number larger than 1. This problem is revised so that a moderator of mass number equal to 1 can also be treated.

1499 T Civil Engineering and Structural Research. Analysis of Plates Containing Holes. This analysis is primarily concerned with an isolated flat plate (slab) with arbitrarily set boundary conditions and containing rectangular holes. Both rectangular and square plates will be considered with size of hole, shape of hole, and location of hole as variables. In addition to uniform loads on the plate, line loads will be introduced around the holes and the plate will be stiffened by beams around the holes.

The mathematical formula involved is the plate equation

$$\frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} = q/D \text{ .}$$

Where: w - Deflection of middle surface

q and D - Constants

x, y - Rectangular Coordinates .

In order to satisfy the complicated boundary conditions in the region of the hole and at the same time satisfy the boundary conditions on the edge of the plate the method of finite difference equations will be used. A very fine network will have to be used due to the fact that the size of the hole is small compared to the size of the plate. Thus each solution for a given set of boundary conditions will involve the solution of from 50 to 125 simultaneous equations. These solutions will provide for the determination of bending moments and shears at any point in the plate.

1500 T Agricultural Economics. Correlation Analysis - Milk Distribution. This problem concerns an examination of fluid milk processing and distribution. The Illiac will be used to determine the extent of the relationships among several variables associated with efficiency. The method used will be correlation analysis.

1501 Digital Computer Laboratory. Static, Spherically Symmetric Relativistic Gas. Einstein's equations are to be solved for the static, spherically-symmetric case. The boundary conditions are that the solution inside the mass must agree on the boundary with the Schwarzschild solution outside. An equation of state (that of a relativistic gas, isentropic motion) is imposed. Dimensionless variables are used, and the set of equations to be solved numerically is:

$$\frac{dM}{dR} = \left[\frac{P}{\Theta}(y+1) - u_c P\right] R^2$$

$$\frac{dy}{dR} = -u_c (1+y) \frac{M + u_c PR^3}{R^2(1 - 2u_c \frac{M}{R})}$$

$$\frac{dP}{dR} = \frac{P}{u_c \Theta} \frac{dy}{dR}$$

$$\Theta = \frac{1}{u_c x} \quad : \quad y = \frac{k_3(x)}{k_2(x)} - 1$$

where u_c is a constant proportional to the central temperature, and k_n is a Bessel function. The integration starts at $R = 0$ and proceeds until $P = 0$.

1502 T Music. Music Composition and Printout. This will be an attempt at using statistical methods to produce a four voice fugue. Random numbers are generated and associated with pitch, rhythm, dynamics and other aspects of tone production. Statistical and other tests will be run on the numbers generated to see if they are usable at this point in the fugue. An attempt will be made on the basis of the results of this project to clarify or explain some of the problems of harmonic or contrapuntal practice as it exists today through analysis.

1503 Agricultural Economics. Commercial Feed Use. An endeavor is being made to estimate quantities of purchased supplemental feeds for different classes of livestock for different counties in Illinois. It is necessary to discover relationships that exist in consumption of different types of feed and between feed use and livestock product output. Several multiple correlation analyses will be used in developing these estimates.

1504 Bureau of Economic and Business Research. Analysis of Business and Stock Ownership. A number of measures (both economic and psychological) have been obtained for a sample of 140 persons. The first problem is to determine what linear combination of the various measurements will "best" discriminate between the two groups: owners of business vs. nonowners; owners of stock vs. nonowners. The method of discriminant analysis will be used to obtain the discriminant function. This requires computation of variances and covariances, and the solution of a system of equations.

Multiple regression analysis will then be used to obtain a function for prediction of the amount of stock owned.

Table I shows the distribution of Illiac machine time for the month of September.

TABLE I

	Hrs:Min	
Regular Maintenance	84:00	
Unscheduled Maintenance	22:13	
Drum Engineering	21:06	
R.A.R.	:11	
Leapfrog	16:18	
Library Development	3:04	
		146:52
Use by Departments		
Classes	:24	
Agricultural Economics	2:36	
Aeronautical Engineering	1:34	
Agronomy	20:43	
Marketing	:13	
Animal Science	8:09	
Astronomy (Nonr 1834(22))	:42	
Astronomy (NSFG 5512)	:10	
Bureau of Educational Research	28:30	
U.S.Navy (9840-0383)	:59	
Veterinary Medicine (MD 728 Off. Surg. Gen.)	:32	
Veterinary Medicine (E 2087)	:14	
Veterinary Medicine (Exp. Sta. 70-316)	:06	
Chemistry	85:49	
College of Medicine	:04	
Coordinated Sciences Laboratory	52:53	
Botany - Eastern Illinois University	:41	
Electrical Engineering (NSFY 32-40-266)	10:35	
Electrical Engineering (NSFG 7421)	1:31	
Electrical Engineering (AF 6079)	1:02	
Electrical Engineering	1:44	
Education	2:57	
Economics (NSFG 7056)	6:21	
Economics	:27	
Digital Computer Laboratory (Task 27)	14:09	
Digital Computer Laboratory (AEC-AT(11-1)415)	2:00	
Digital Computer Laboratory	:04	
I.R.E.C.	:07	
Physics (Nonr 1834(12))	:57	
Physics (AF 662(46-22-55-302))	:12	
Physics	7:47	
Music	:05	
Stanford Research Center (Nonr 2778(100))	3:14	
Psychology (AF 49(638)371)	7:50	
Psychology (P.H. 1715)	11:49	
Psychology (ONR 1834(11))	:26	
Psychology	24:24	
Sociology (Ford Found. 44-32-69-329)	:38	
Sociology	2:31	

Use by Departments
(cont'd.)

	Hrs:Min		
Structural Research (AF 464)	3:39		
Structural Research (A.A.S.H.O. Road Test)	1:52		
Structural Research (NSF 6572)	3:05		
Structural Research (Nonr 1834(03))	6:24		
Structural Research (Hwy. Brdg. 47-22-20-307)	6:58		
Structural Research	26:28		
Theor. and Applied Mechanics (ORD 593)	:17		
Theor. and Applied Mechanics	2:06		
State Water Survey (SC 75055)	3:22		
State Water Survey	:26		
Institute of Communications Research (PH 9067C)	1:07		
Mechanical Engineering (Martin Co.)	2:00		
Mechanical Engineering	4:10		
Mining and Metallurgical Engineering (AF 3789)	:08		
Mining and Metallurgical Engineering	3:10		
Zoology	7:14		
Mathematics	2:36		
Michigan State University	2:19		
Physical Education	:09		
		382:39	
			529:31

Error Frequency and Analysis

The Illiac is normally used for "engineering" and maintenance between 7 a.m. and 10 a.m., and for a check of its performance between 5:30 p.m. and 6:30 p.m. of each weekday. Since the periods between 7 a.m. and 10 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance and laboratory functions, it is more instructive for an error standpoint to look at the periods between 10 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind a summary table has been prepared, using the period between 10 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:30 - 6:30 period (when the machine is checked), if no errors are to be found, the time is given to the

"running column". Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This overall system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for June.

TABLE III

Control	2
Arithmetic	1
Memory	3
Drum	13
Reader	3
Punch	3
Unknown	7
Input-Output	1
Run-over from Sched. Main.	1
Total	34

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/1/59	19:52	:01	4:07	1	(1) White switch failure	0	:40	0
9/2/59	19:40	:00	4:20	0		0	:40	0
9/3/59	20:02	:00	3:58	0		0	:40	0
9/4/59	21:00	:00	3:00	0		0	:40	0
9/8/59	20:40	:20	3:00	1	(1) Unknown	0	:40	0
9/9/59	21:11	:19	2:30	2	(1) Drum failure (2) Punch #5	0	:49	0
9/10/59	21:25	:00	2:35	0		0	:40	0
9/11/59	19:29	1:46	2:45	1	(1) Drum failures	0	:44	0
9/14/59	19:08	:30	4:22	3	(1) Control error (2) Unknown (3) Memory error position 2^{-18}	0	:56	0
9/15/59	19:39	:38	3:43	2	(1) Unknown, (2) Reader "B" error	0	:40	0
9/16/59	19:10	1:12	3:38	1	(1) Drum Failure	0	:40	0
9/17/59	20:38	:23	2:59	4	(1)(2)(3)(4) Drum failure	0	:40	0
9/18/59	21:05	:03	2:56	2	(1) Drum failure (2) Leapfrog failed, reason unknown	0	1:25	1
9/21/59	19:25	:00	4:35	0		0	:41	0
9/22/59	19:24	:12	4:24	1	(1) Drum failure	0	:40	0
9/23/59	16:56	4:45	2:19	4	(1) Memory error 2^{-7} (leapfrog) (2) Drum failure (3) Memory error 2^{-20} (4) Input-Output error	0	:45	1
9/24/59	9:54	9:06	5:00	3	(1) Run-over from scheduled maintenance (2) Drum failure, (3) Drum failure	0	:40	0

TABLE II (Cont'd.)

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
9/25/59	18:12	1:23	4:25	4	(1)(2)(3) Unknown (4) Arithmetic error	0	1:18	1
9/28/59	17:03	2:36	4:21	3	(1) Reader "F" error (2) Drum failure (3) Reader "H" error	0	:45	0
9/29/59	20:20	:00	3:40	0		0	:40	0
9/30/59	20:52	:17	2:51	2	(1) Punch "4" error (2) Punch #5 error	0	:00	0
TOTALS	405:05	23:31	75:28	34		0	15:23	3

PART IV

IBM 650 USE AND OPERATION

New 650 Codes

During the month of September six new routines were added to the Digital Computer Laboratory 650 Library.

S5'-47' <u>Floating point E^A, 10^A, Sinh A, Cosh A.</u> This is a combined routine which will produce any one or a combination of the functions E^A, 10^A, Sinh A, Cosh A, for an argument A.

(M. T. Gray)

I1'-48' <u>Table Look-up Interpolation Routine, Floating Point.</u> This routine carries out linear interpolation in a set of tabulated values stored on the drum.

(K. E. Shannon)

R6'-49' <u>Cube Root Subroutine (Fixed).</u>

(K. E. Shannon)

I2'-50' <u>Double Table Look Up Interpolator, Floating Point.</u> This routine linearly interpolates with respect to both arguments in a table of a function of two variables stored on the drum.

(K. E. Shannon)

M4'-51' <u>Fixed Point Matrix-Vector Multiplication.</u> This subroutine multiplies a vector V by a fixed point single-precision square matrix M of order less than 42 in order to form a transformed vector.

(M. T. Gray)

I3'-52' <u>Parabolic Interpolator (Floating Point).</u> This routine fits a second degree polynomial to three adjacent points in order to carry out interpolation in a table of functions of one variable stored on the drum.

(K. E. Shannon)

IBM 650 Usage

During the month of September specifications were presented for 7 new problems. This list does not indicate how the IBM 650 was used because large amounts of machine time may have been consumed by problems with numbers less than 44'. Numbers followed by T are for theses.

44' Psychology. Normalized Standard Scores. This computational work is a basic part of a study of adult personality structure. Psychological test measurements on 170 subjects, including college students, alcoholics, and criminals, are first normalized and then intercorrelated to form a 110 x 110 matrix of tests. The matrix is factor analyzed and the arbitrary reference structure is rotated to simple structure. Scores for the three populations will be computed on the factor thus computed.

The current IBM 650 program is intended to accomplish the following steps:

1. Compute normalized standard scores (McCall's T scores) on 110 variables, 170 observations (means equal to 50, sigmas equal to 10).
2. Obtain means and standard deviations for the raw scores.

45' T Physics. Lattice Sum. The problem is to find the electric field gradient at a lattice point due to all other lattice ions within a certain radius in an elongated face centered cubic crystal; i.e. one with primitive vectors (a,0,0), (0,a,0), (0,0,c). This quantity is $\alpha \sum_{\substack{\text{lattice} \\ \text{points}}} \frac{3z^2 - r^2}{r^5}$.

The program generates the lattice points and calculates the value of the function. Due to symmetry of the lattice only about 10% of the points within a sphere need be taken, the other 90% containing points equivalent to these. The outer radius depends on the (unknown) convergence of the function.

46' Agronomy. Illinois Spring Oat Variety Demonstration. Ten oat varieties were tested for yield and test weight for various locations within the state. Analysis of Variance is used to determine if the varieties are significantly different in yield or in test weight.

47' Physics. Aluminum Integration. The problem consists of finding the area under a complex function. An accurate approximation may be expressed by a quadrature formula derived by Gauss.

In the process a value for a suitable x_i (where x is the abscissa of the complex function) determines the real (R) and imaginary (I) value of the complex function at that point. y is a function of the sub-interval (v_i) into which the function is divided by Gauss' formula.

In this problem the integral of the subdivision is to come out in the form $I = \log_e \Gamma + i\Theta$ where

$$\Gamma = \sqrt{\left(1 + \frac{R}{y^2}\right)^2 + \left(\frac{I}{y^2}\right)^2}$$

and

$$\Theta = \arctan \frac{\frac{I}{y^2}}{1 + \frac{R}{y^2}} .$$

If the integral of the subdivision is denoted as $\log_e \Gamma + i\Theta$ then it can be decomposed into two parts. They are $\varphi(v_i)$ and $\varphi(-v_i)$, where v_i is the dividing factor according to Gauss' formula. Then the total integral of the subdivision is equal to $g_i[\varphi(v_i) + \varphi(-v_i)]$ where g_i is a weighting factor for each subdivision.

48' Psychology. Psychometrics Research. The behavior of measures of "similarity" between two test vectors is being investigated. Various "components" of each vector have been punched into cards along with the scalar product of pairs of vectors from two different origins, for 163 subjects and two sets of vectors. Each set contains a total of 27 components.

49' Agronomy. Variety Testing of Barley. Barley varieties are tested for yield and other characteristics at various locations within the state. Analysis of Variance is used to determine whether the varieties are significantly different in yield and the other characters tested.

50' Agronomy. Variety Testing of Wheat. Wheat varieties are tested for yield and other characters at various locations within the state. Analysis of Variance is used to determine whether they are significantly different in yield and the other characters tested.

Table I' shows the distribution of the IBM 650 machine time for the month of September.

TABLE I'

	Hrs:Min		
Regular Maintenance	18:00		
Unscheduled Maintenance	2:17		
Air Conditioning Maintenance	5:35		
Library Development	9:06		
Log Summary	:20		
Wasted	75:02		
		110:20	
Use by Departments			
Statistical Service Unit	45:54		
Theor. and Applied Mechanics	4:04		
Structural Engineering	15:38		
Agronomy	2:30		
Physics	9:19		
Mathematics 395	1:20		
		78:45	
			189:05

Error Frequency and Analysis

The IBM 650 is normally on from 8 a.m. to 5 p.m. The machine is used for preventive maintenance from 8 a.m. to 12 noon on Wednesdays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for September.

TABLE III'

650 Console	3
407 Printer	1
533 Read Punch	6
727 Tape units	4
Warm-up time longer than usual	2
Air Conditioning	2
Total	18

TABLE II

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
9/1/59	7:15			1:45	0		
9/2/59	3:22	4:00		1:38	1		Blank columns in output from 533. Reason unknown.
9/3/59	6:41			2:19	0		
9/4/59	3:17			5:43	0		
9/8/59	4:20			4:40	0		
9/9/59	2:36	4:00		2:24	0		
9/10/59	3:50		:02	5:08	3		(1)(2) Double bits in distributor. (3) Card jam in 533 output.
9/11/59	3:31	2:00		3:29	0		
9/14/59	2:09			6:51	0		
9/15/59	4:17			4:43	0		
9/16/59	1:48	4:05		3:12	0		
9/17/59	6:54			2:06	3		(1)(2) Output had double punches. (3) Dirt in contact in 407.
9/18/59	6:10			2:50	2		(1)(2) Double bits in position 4 of program register.
9/21/59	4:59		:30	3:31	2		(1) Double bits in position 4 of program register. (2) Roller on tape unit was "pitted".
9/22/59	2:27			6:33	0		
9/23/59	2:25	3:55		2:40	0		
9/24/59	5:27		:48	2:45	2		(1) Tape unit did not do a load rewind correctly. (2) Tape indicate on - no reason.
9/25/59	4:54		:32	3:34	2		(1) Card jam in 533 read. (2) Card jam in 533 punch.

TABLE II' (cont'd.)

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
9/28/59	:50			2:35	2	5:35	(1)(2) Air conditioning out on 650.
9/29/59	6:30		:25	2:05	1		(1) Tape piled up in vacuum tubes.
9/30/59	4:29			4:31	0		
TOTALS	88:11	18:00	2:17	75:02	18	5:35	

PART V

GENERAL LABORATORY INFORMATION

Seminars

"A Survey of Asynchronous Theory", by Dr. David E. Muller, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, September 21, 1959.

"The Order Code for the New Illinois Computer" by Dr. Donald B. Gillies, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, September 28, 1959.

Personnel

The personnel associated with the department and, hence, the contributors to this report are:

Alexander, Richard F., Student Assistant (Started Sept. 28)
Avizienis, Algirdas A., 1/2-time Research Assistant (Started Sept. 16)
Bahls, James E., Jr. Laboratory Mechanic
Baur, John W., 1/2-time Research Assistant
Blankfield, Mrs. Judith, Research Associate (Started Sept. 16)
Blencoe, Robert W., Computer Operator I
Bowes, Mrs. Doris E., 1/2-time Research Assistant
Brearley, Harrington C., Jr., Research Assoc.Prof. of Elec.Eng.(Started Sept.1)
Briley, Bruce E., 1/2-time Research Assistant (Started Sept. 16)
Carter, Clifford E., Electronics Engineer
Clark, Miss Helen B., Secretary
Cummins, Richard L., 1/2-time Research Assistant
Davenport, Mrs. Margery S., Clerk-Stenographer II(resigned Sept. 8)
Dickman, Kern W., Research Assistant
Ellsworth, Mrs. Jean E., Clerk-Stenographer III
Field, William L., 1/2-time Research Assistant (Started Sept. 16)
Fileccia, John L., Electronics Technician I
Fisherkeller, Miss Mary Anne, 1/2-time Research Assistant (Started Sept. 16)
Flenner, Ross H., 1/2-time Research Assistant (Started Sept. 16)
Fosdick, Lloyd D., Research Asst. Prof. of Physics
Foster, Merlin J., Computer Operator I
Foulk, Clinton R., 1/2-time Research Assistant (Started Sept. 16)
Frazer, W. Donald, 1/2-time Research Assistant (Started Sept. 16)
Gear, Charles W., 3/4-time Research Assistant
Gillies, Donald B., Res. Assoc. Prof. of Appl. Math.
Gray, Mrs. Mary T., Research Assistant
Guckel, Henry, 3/4-time Research Assistant (Started Sept. 16)
Gustafson, Ronald A., Electronics Technician I
Huffman, W. Logan, Computer Operator II
Irwin, Arlyle F., Electronics Technician I
Johnson, Noel H., 3/4-time Research Assistant
Kerkering, Thomas E., Sr. Laboratory Mechanic
Kimbrough, Mrs. Lynn, Keypunch Operator I (Started Sept. 14)
Krabbe, Shirlie P., Electronics Technician II for Illiac

Kunihiro, Toshiro, 1/2-time Research Assistant
Lacy, Donald L., 1/2-time Teaching Assistant (Started Sept. 16)
Leslie, James D., 1/2-time Research Assistant
Lierman, Richard A., Electronics Technician I (Resigned Sept. 4)
Liu, Chao-ning, 1/2-time Research Assistant
Lopeman, Harold E., Electronics Engineer
Meagher, R. E., Head of the Laboratory (on leave beg. April 1, 1959)
Metze, Gernot A., Research Asst. Professor
Michael, George W., Administrative Assistant
Miller, J. C. P., Visiting Professor (Started Sept. 16)
Muerle, John L., 3/4-time Research Assistant
Muller, David E., Res. Assoc. Prof. of Appl. Math.
Murrell, T. A., Assoc. Prof. of Elec. Eng.
Naikelis, U. Stanley, 1/2-time Teaching Assistant (Started Sept. 16)
Oare, John W., Draftsman
Peek, Levin J., 1/2-time Research Assistant
Pelg, Edmund, Electronics Technician II for Illiac
Penhollow, John O., 1/2-time Research Assistant (Started Sept. 16)
Penny, Samuel J., 1/2-time Research Assistant (Started Sept. 16)
Piper, Thomas C., 1/2-time Research Assistant. (Started Sept. 16)
Poppelbaum, W. J., Res. Assoc. Prof. of Elec. Eng.
Raff, Mrs. Murna J., 1/2-time Teaching Assistant
Ray, Sylvian R., 3/4-time Research Assistant
Reeves, Artie L., Electronics Technician I
Resh, James A., 1/2-time Research Assistant
Richardson, Warren V., Tape Equipment Tech. I
Rittis, James A., Draftsman
Rivera, Ralph M., Jr. Laboratory Mechanic
Robertson, James E., Research Professor of Elec. Eng.
Rosenkrantz, Walter A., 1/2-time Research Assistant (Started Sept. 16)
Rudman, Mrs. Linda G., Tabulating Machine Operator I
Russell, Miss Ramona J., Computer Operator II
Saathoff, Miss Norma I., Computer Teletype Operator
Serio, Frank P., Electronics Technician II
Shively, Richard R., 1/2-time Research Assistant
Snyder, James N., Research Professor of Physics
Sullivan, John D., Electronics Technician II
Swartwout, Robert E., 3/4-time Research Assistant
Taub, A. H. Research Professor of Appl. Math. (Acting Head of the Lab)
Trnka, Mrs. Pauline, Clerk-Stenographer II (Started Sept. 15)
Wenta, Joseph V., Elec. Technician II for Illiac
Wheeler, David J., Research Associate Professor (through Sept. 20)
Wong, Alfred Y. F., University Fellow

The Department Advisory Committee consists of Professors H. C. Brearley, L. D. Fosdick, D. B. Gillies, G. A. Metze, D. E. Muller, T. A. Murrell, W. J. Poppelbau J. E. Robertson, J. N. Snyder and A. H. Taub.

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - SWITCHING CIRCUIT THEORY

PART III - ILLIAC USE AND OPERATION

PART IV - IBM 650 USE AND OPERATION

PART V - GENERAL LABORATORY INFORMATION

October, 1959

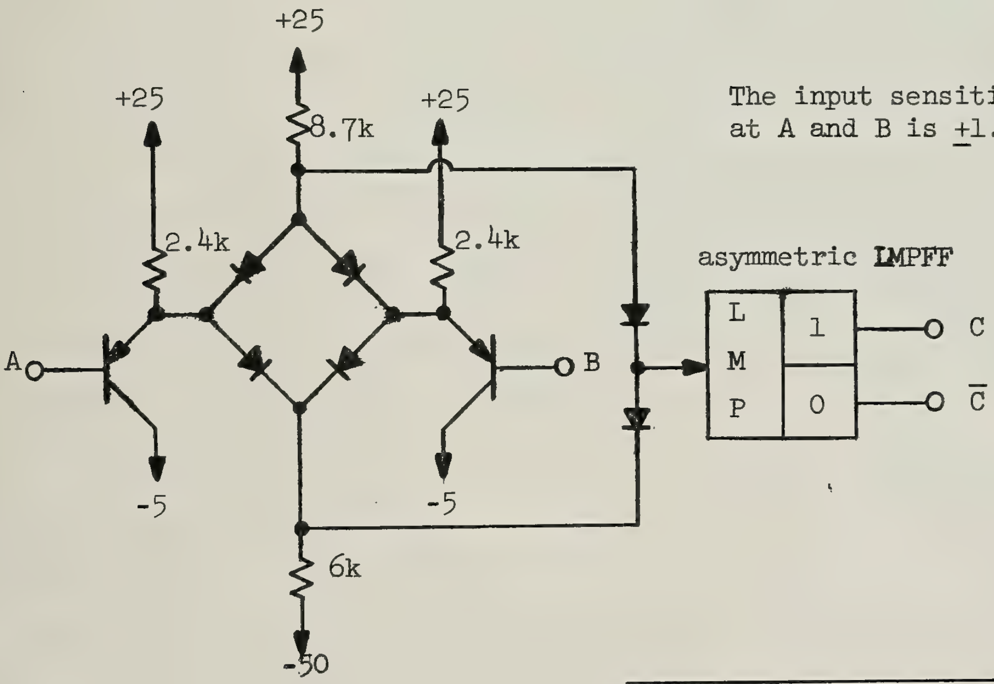
PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission, in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

1. Last Moving Point Circuits

A last-moving-point storage element is particularly desirable for the control section of the new computer. Using the asymmetric last-moving point flipflop, a LMP (last moving point) C-ELEMENT was designed. This circuit has two collector delays, and is therefore as fast as the standard C-ELEMENT. There are two versions: one is a true C-ELEMENT and the other is a C-ELEMENT with one forbidden state.

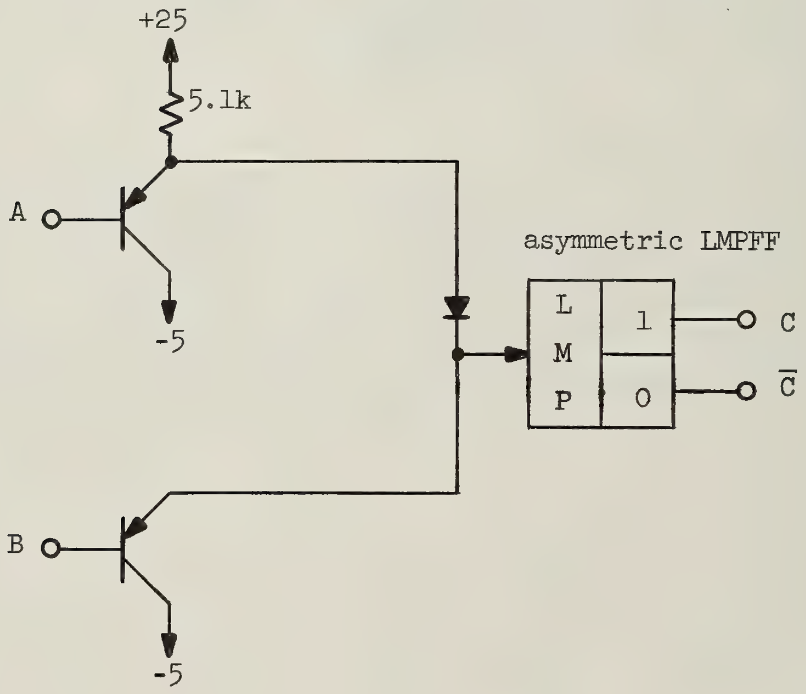


The input sensitivity at A and B is ±1.0v.

A	B	C
0	0	0
0	1	Does Not Change
1	0	Does Not Change
1	1	1

Figure 1
True C-ELEMENT

The other version is simpler but has one disallowed state.



The input sensitivity at A and B is ± 1.2 volt.

A	B	C
0	0	0
0	1	Does not Change
1	0	Forbidden State
1	1	1

Figure 2
C-ELEMENT with one Forbidden State

2. Shifting Register Test Unit

The fan serving to circulate the conditioned air in Room 115 was turned off after the unit had run for 845 hours without error. The unit failed within 20 minutes. After turning the fan back on the unit was restarted successfully. It failed, however, the next day when it went into an illegal state. Since then the unit has continued to run.

(G. Metze)

3. 52 Bit Shifting Register

Last month the task of correcting the logical diagram for the speed-independent control for test unit #2 was completed. Since then this design has been checked on Illiac by use of the Q-5 (Complete Circuit Analysis) routine and was found to be semimodular. From this logical diagram a complete circuit schematic has been drawn. Use has been made of both the standard circuits from the circuit book and also the matrix circuitry. The speed-independent control (excluding indicator lamp circuitry) uses 42 transistors and 132 diodes whereas the equivalent portion of the clock control uses 25 transistors and 40 diodes.

One of the purposes of the test unit is to obtain practical information usable in the construction of the final machine. It is apparent that the maximum of useful data will be obtained from the test unit if the design concepts and philosophies envisioned for the computer are also utilized in the test unit. In an effort to accomplish this, the opinions of all staff members were solicited by means of an internal report, File No. 300, which describes both the speed-independent and the clock controls and also the assumptions made and compromises employed in arriving at workable control systems.

(R. E. Swartwout)

4. Arithmetic Unit Design

The logical diagrams for the two standard base 4 pseudo-adders in the MAU (main arithmetic unit) were completed. These diagrams and the logical equations on which they are based are available upon request.

Work was started on the design of a division predictor which is an essential unit for doing division by the Robertson division process. The basic

ideas underlying the predictor and the division process in general were outlined by D. J. Wheeler in Report No. 92, page 11. The aim of the present work is to produce a division prediction circuit that can be realized at a reasonable cost in terms of components and yet have sufficient speed and the required precision. The latter is determined by the machine base and the available multiples of the divisor (2M, M, 0, -M, -2M). Thus the design problem as usual is reduced to the problem of finding a good balance between speed and equipment cost. Two major approaches to this problem have been made so far. One approach makes use of a subtractor in which both carries and borrows may arise. The other uses an assimilator over eight bits followed by a comparator. The latter seems to offer a better compromise between speed and cost, and unless further difficulties are encountered, this scheme will be used in the final design.

(J. O. Penhollow)

The circuitry for recoding the multiplier has been designed. However, the original intention of using only non-restoring circuits in this logic was found impracticable by the following combination of factors:

a) The option of skipping digits necessitates that the recoder be preceded by the selector, or shift gates.
b) The use of high level selectors on F-element outputs precludes the use of these outputs in driving other standard logic.
c) The same F-elements involved in holding the multiplier digit of current interest must also drive the quotient correction and zero detection logic.

A study of whether the resulting added collector delay will add to the MAU cycle, and the design of a more elaborate recoder to circumvent this delay, is being deferred until laboratory data on the delay of an F-element are available.

Both in implementing the order code and as a result of direct requests from the Planning Group, the following modifications to MAU performance, as described in Report 92, are being considered:

a) In multiply, if the option of using the address itself as operand is exercised, the contents of the A register will be gated to the M register to act as -icand, and a special 13 bit bus will gate the operand into the Q register to act as -ier. This is done in order to realize time saving.

b) The requirement that a divisor be normalized is removed; if this operation is attempted, the divisor will be normalized automatically prior to division. This is possible due to the added provision to shift A and S left, not affecting R and Q.

c) An indicator will be set to 1 following every arithmetic operation rendering (AQ) = 0.

(R. R. Shively)

A file report which describes in detail the functions of the EAU (Exponent Arithmetic Unit) is in preparation.

Problems of floating point addition were investigated. A summary of the operations in f.p. addition was prepared and presented for consideration to the control design group.

The tentative order code (File No. 299) was evaluated with respect to the requirements which are imposed on the EAU (especially the fixed point and integer operations).

Preparation of a table of operations of the EAU was started; this table shall be the basis for a complete flow diagram, which defines the EAU.

(A.A. Avizienis)

The over-all layout of the MAU was investigated in order to arrive at a chassis size optimal with respect to number of pin connections, shortness of leads, etc. It appears that a satisfactory arrangement can be obtained if two quaternary digits of a register (and their associated carry storage bits) are located within one chassis.

(C. E. Carter and H. E. Lopeman)

5. Input-Output and Auxiliary Storage

The FR-300 tape unit has been the center of attraction during the month of October. It was found early in the month that (apparently) the majority of our difficulties with this unit were a result of improper alignment relative to each other of the various tape rollers and guides. Ampex has supplied and installed new vacuum chambers which apparently will, with careful adjustments, eliminate our troubles with tape slippage. The results thus far have been very encouraging.

(L. J. Peek, Jr.)

Redesign of the J-element circuit for operation with the new standard voltages was started; new component values have not been checked on the Illiac Tolerance Analysis Program (1455). Work was begun on a study of the effect of various mechanical and electrical tolerances on maximum packing density on the FR-300, using tolerance data recently obtained from Ampex.

(R. L. Cummins)

The ring counter is now operating. The main cause of the ring counter's failure to operate was diode failure - shorts, low reverse voltage breakdowns, and opens. The Q5's and Q10's which were found bad were replaced with T1G's.

(T. C. Piper)

6. Core Storage Unit

The X-Y and digit drivers have been redesigned so that the final transistor (2N1072) is driven by an NPN-PNP emitter follower ("pull-up, pull-down EF) instead of a common-emitter switching stage. This produces several desirable effects as follows:

1) Delay time in the driver is reduced (from 100 to 60 mμs.)
2) Quiescent power is reduced.
3) More drive current can be delivered to the 2N1072 base for a given NPN transistor in the emitter follower. This has the effect of either relaxing some requirements on the NPN or decreasing the sensitivity of 2N1072 switching to parameter variations, or both.

The sense amplifier design is virtually complete. The major factor which cannot be adequately extrapolated from the present experimental arrangement is the form of the noise which may be present on the digit wires when there are 54 adjacent wires instead of 3.

(S. R. Ray)

Work was continued on the design of the address decoder for the memory. The logical arrangement has essentially been decided, with but a few minor variations yet to be explored. The actual circuit design is now in progress; diode logic will make up the bulk of the circuitry.

A number of logic circuits were tested for speed-independence on Illiac.

(B. E. Briley)

The variable voltage regulators for the power transistor tester were redesigned to obtain better load regulation and switched, rather than plug-in, ranges. The tester for medium and high power transistors is under construction.

(J. D. Leslie)

Calculation is in progress, using Problem Specification #1455 on Illiac, to calculate the D.C. drift of the memory sense amplifier designed by S. Ray dated 23 September 1959. These calculations will also be used to modify component values in the sense amplifier for optimum performance.

(J. L. Muerle)

PART II

SWITCHING CIRCUIT THEORY

(Supported in part by the Office of Naval Research under Contract Nonr-1834-(27).)

The model of an asynchronous circuit, which has been used in the study of speed independence semi-modularity and distributivity, makes use of a set of n functions $Z_i' = f_i\ (Z_1, Z_2, \ldots, Z_n)$; $i = 1, 2, \ldots, n$ to describe the circuit. The variables Z_j and Z_j' are signals in the circuit and in the binary case have the range $\{0, 1\}$.

In this model each function f_i is treated as if it were a function of the n variables $Z_1, Z_2, \ldots, Z_n$ although in practice it is often independent of many of them. Existing tests for speed independence, semi-modularity, and distributivity are based upon the n-variable dependence with the result that all possible states must be generated in such tests.

To take advantage of the fact that many functions f_i do not depend upon all n variables, we introduce an n x n connection matrix M of 0's and 1's such that the i x j^{th} element of M is a 1 if and only if f_i depends specifically upon Z_j. Tests for semi-modularity are being developed which take account of M with the result that not all the states need be generated during the test.

(W. D. Frazer)

PART III

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of October one new routine was added to the Illiac Library.

M28-270 Matrix Multiplication with or without Rescaling (SADOI). This is a general matrix multiplication routine which allows the user many options. The input to the routine may consist of either matrices read from punched paper tape or matrices previously stored on the drum. The output product matrices may either be punched on paper tape or stored onto the drum. During this process the matrices can be scaled by specified powers of 10.

(K. W. Dickman)

Illiac Usage

During the month of October specifications were presented for 33 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1505. Numbers followed by T are for theses.

1505 Chemistry. The Generation of Non-Intersecting Random Walks. Because of the formal similarity between polymeric compounds and non-intersecting random walks, a study of the properties of these walks has been very helpful in elucidating some properties of high polymers. In the past each time a set of non-intersecting random walks has been needed for various computational purposes, they have been generated anew on the Illiac. The present program seeks to eliminate the need for such repetitious generation by the formation of a 'bank' of such walks on tape. This bank will then be used as a source of walks to be fed back into the Illiac as needed for further computation at a later date. The saving of computer time in future programs should be considerable.

In this program non-intersecting random walks are generated by a step-wise procedure. From a given point a random number is used to determine the direction of the step to the next point. A backwards check is then made to determine if this point has been previously occupied. If it has not, the process is continued until a preset cutoff point is reached, whereupon the complete walk is punched out. Otherwise, a walk of intermediate length is punched. In any case, the process is then restarted.

1506 Digital Computer Laboratory. Logical Design of the New Illinois Computer. The Illiac will be used to aid in the logical design of the new Illinois computer. Routines for checking the sequencing of asynchronous circuits have already been written (Q3,4,5) and others will probably be written in the future. As various parts of the control are designed they should be checked for speed independence and to determine whether or not the sequencing is correct.

1507 Marketing. Factor Analysis of Food Expenditures of U.S. Households. From a sample size of 500 U.S. households with 35 variables, the relationships between consumption expenditures and family characteristics is to be analyzed.

The Illiac is used to compute the simple correlation matrix, and then use factor analysis to show what relationships exist.

1508 Aviation Psychology Laboratory. Cross Correlations. This program will calculate a series of cross correlations with regular time lags applied to the second variable. The first coefficient is:

$X_1\ X_2\ X_3$ - - - - X_n correlated with $Y_1\ Y_2\ Y_3$ - - - - Y_n . The second is
$X_3\ X_4\ X_5$ - - - - X_n correlated with $Y_1\ Y_2\ Y_3$ - - - - Y_{n-2} . The third is
$X_5\ X_6\ X_7$ - - - - X_n correlated with $Y_1\ Y_2\ Y_3$ - - - - Y_{n-4} , etc.

The research problem is to investigate the nature of subject response to a 2-dimensional pursuit tracking task. It is expected that this series of cross correlations will show the dependence or independence of subject response to the two tasks or variables and also the presence or absence of alternating attention from one task to the other. In the presence of alternating attention the successive coefficients will give a measure of the rate of shifting attention.

1509 Psychology. Motivation and School Performance. This study will involve standardization of a Motivation Test and a subsequent R-type factor analysis of this instrument and criteria data related to behavior and school performance. Additional research relating specific ergs and sentiments to school subject matter and method of instruction will eventually involve further analyses.

There will be approximately 100 variables, 25 factors and 300 subjects in this study. There will be probably 8 to 10 rotations to attain simple structure.

The purpose of the study or studies initiated under this project will be to relate school performance to refined objective measures of motivation as are evolving from past studies from this laboratory.

1510 Psychology. Motivation Conflict. This study will involve a single P-technique Factor Analysis and some associated R-technique analyses to ascertain relationships between motives and motivational conflict and psychopathology.

The P-technique on factor analysis will involve the from 50 to 60 variables measured seventy-five to one hundred times on the same individual and factored for twenty factors. Two or three studies of this size may have to be completed if ambiguous results should indicate it.

The R-technique Study will involve the relationship between normal and pathological subjects on motivation measures. 75 to 100 variables will be analyzed with 100-150 subjects. Twenty factors will be extracted and rotated to simple structure.

1511 State Water Survey. Illinois Drought Study. The study involves the analysis of 50 years of precipitation records at 60 stations in Illinois to determine the frequency distribution of drought periods having durations of 3 months to 5 years.

Monthly totals will be used in the calculation of moving averages for periods of 3, 6, 12, 24, 36, 48, and 60-months. A complex sorting will follow to obtain ranked independent data for determination of the frequency distribution. A least squares fit may be used to determine a frequency curve for the sample data.

1512 Institute of Communications Research. Facial Fusion Study. Poses of Different Emotions are Rated by Subjects Using the Semantic Differential. The facial expressions are presented by stereoscopic technique. In some cases different expressions are used for each eye in order to obtain a fusion effect.

The study is meant to investigate the structure of the semantic meaning of these expressions and to test the congruity hypothesis.

1513 Psychology. Interpersonal Perception and Adjustment of Group Members. This research involves three specific aims: a) methodological improvements in interpersonal perception measures, and in measures of psychological adjustment; b) further investigation of quasitherapeutic processes in small groups; and c) investigation of relationships between experimentally induced changes in interpersonal perception and changes in social behavior.

The use of the Illiac in this research would involve standard library routines primarily. Such statistical techniques as factor analysis, multiple correlation and regression, and analysis of variance will be necessary in order to obtain solutions to some of the problems. In addition, it may be necessary to develop special programs on occasion for solution of more complex problems.

1514 Digital Computer Laboratory. Circuit Design. A tolerance analysis of the basic circuits of the new computer to determine node voltage spreads for the circuit drawings is to be made. A last-moving-point flipflop and a last-moving-point F-element for the new computer will also be investigated.

1515 Digital Computer Laboratory. Control Circuit Analysis and Synthesis. Library Routines Q1 through Q5 and new routines now in preparation will be used for the analysis and synthesis of the control logic for the new computer.

1516 Mechanical Engineering. Heat Transfer Coefficient Calculation. A series of ten nonlinear heat transfer equations will be solved by successive approximation to determine the heat transfer coefficients from laboratory data.

1517 Bureau of Educational Research. Heterogeneous Alpha. Problem Number 1345, a routine which generates matrix of covariance and phi coefficient when given item difficulties and tetrachoric correlation coefficient, has been programmed.

This program is the revision of it, to make it possible to take random values of tetrachoric coefficient and to stratify the item difficulty at desired fineness.

1518 Digital Computer Laboratory. Auxiliary Storage Analysis and Synthesis. Circuit analysis and synthesis routines prepared under problem specification numbers 1206, 1250, 1308, and 1455, and circuit synthesis routines now in preparation will be used for the analysis and synthesis of circuits of input, output and auxiliary storage units in the new computer.

1519 Digital Computer Laboratory. Basic Circuit Analysis and Synthesis. Circuit analysis and synthesis routines prepared under problem specification numbers 1206, 1250, 1308, and 1455, and circuit synthesis routines now in preparation will be used for the analysis and synthesis of basic circuits for the new computer.

1520 Digital Computer Laboratory. Auxiliary Storage Analysis and Synthesis. Circuit analysis and synthesis routines prepared under problem specification numbers 1206, 1250, 1308, and 1455, and circuit synthesis routines now in preparation will be used for the analysis and synthesis of circuits of input, output and auxiliary storage units for the new computer.

1521 Digital Computer Laboratory. Memory Circuit Analysis and Synthesis. Circuit analysis and synthesis routines prepared under problem specification numbers 1206, 1250, 1308, and 1455 and circuit synthesis routines now in preparation will be used for the analysis and synthesis of core memory circuits for the new computer.

1522 Digital Computer Laboratory. Arithmetic Unit Analysis and Synthesis. Circuit analysis and synthesis routines prepared under problem specification numbers 1206, 1250, 1308, and 1455 and circuit synthesis routines now in preparation will be used for the analysis and synthesis of arithmetic unit and control circuits.

1523 Structural Research. Maximum Response of a Multi-degree of Freedom System Subjected to Ground Motion. Program 462 will be used to study the

response of a multi-degree of freedom system subjected to simple ground acceleration pulses. The results will be used to predict the response of actual structures subjected to earthquake or blast forces.

It is anticipated that Program 462 will have to be modified to provide for relative damping instead of absolute damping.

Program 462 solves the differential equation of motion of an "n" mass system using a numerical iterative integration technique.

1524 Chemistry. Calculation of Nuclear Magnetic Resonance Spectra. The research problem involves calculating the spectrum which theoretically should result from a given set of chemical shifts, v_i, and coupling constants J_{ij}, for a system of n nuclear spins ($n \leq 6$).

The program proceeds with this computation through the following main steps:

1. Calculation of a machine representation of the 2^n elementary spin-product functions of the form

$$\phi_j = \prod_{i=1}^{n} I_z(i)$$

   where $I_z(i)$ can be α or β.
2. Division of this set of elementary functions into subsets on the basis of total spin.
3. Computation of the spin-interaction matrix for each of these subsets.
4. Calculation of eigenvalues and eigenvectors for these matrices.
5. Computation of the spectrum as follows:

   Let E_i^k designate the i^{th} eigenvalue for the matrix which arose from the set of functions of total spin k. Let (a_{il}^k) be the corresponding eigenvector. Then the lines of the spectrum will have frequencies

$$E_i^k - E_j^{k-1}$$

   where i, j, k take on all possible values (i.e. values really corresponding to eigenvalues). The relative intensity corresponding to this line is computed as

$$\sum_{l,m}^{*} a_{il}^{k} a_{jm}^{k-1}$$

   where the * indicates that the summation is restricted to values of m and l such that ϕ_m and ϕ_l differ only by a single spin.
6. Simplification and print-out of the spectrum.

1525 Education. Numerical Investigation of Rotation. Experiments with the tolerances in KSL 1.92 will be made. The present rationally determined tolerances appear to require an inordinate amount of computer time. In addition an exploration of an unfortunate tendency for the procedure (or the program) on rare occasions to generate a singular transformation will be made.

1526 T Psychology. Correlation Matrices. Relationships between a large number of predictor variables based on psychological tests, and several criterion scores based on ratings of subjects' situational behavior are being sought. At the same time, the relationships within the predictor variables and within the criterion ratings are to be studied. Finding correlations of each variable with each other variable will permit detailed examination of interrelationships, while comparison of means will be useful for comparison between groups.

1527 Digital Computer Laboratory. Communalities Estimates. There is no answer to the problem of securing accurate communalities for a matrix because the solution is mathematically indeterminate. Because of this several schemes have been devised to estimate communalities. It would be useful as well as valuable in the interest of better research to have an example of each procedure using a matrix whose properties are well known. This would help indicate the limitations and advantages of each type of estimation procedure so that the individual using these routines could make a more objective decision on what procedure to use rather than choosing the procedure which is most commonly used regardless of the particular type of data in hand.

1528 Animal Science. Mouse Insemination. A study is being made to determine how long sperm and unfertilized mammalian eggs can live and retain capacity to fertilize or be fertilized. The mathematical method of least squares will be used to analyze the data.

1529 T Agricultural Economics. Crop Substitution Relationships. This problem is to evaluate the effects of commercial fertilizer use on the substitution relationships between crops found in 2 areas of Illinois in two time periods (1954 and 1958). It is thought that linear programming is the most efficient way of determining these marginal rates of substitution for the crops specified.

Approximately 15 crop rotations (processes) will be used with land and labor as restrictive in each of the sections of the problem with variable pricing of the crops used to determine points on the substitution curves.

1530 Electrical Engineering. Coordinates Conversion. This program converts geographical coordinates into local coordinates, direction and distance. It uses simple spherical trigonometry formulae.

1531 Electrical Engineering. Magnetic Parameters Along a Radio Path. This program is similar to Problem Number 1476. It calculates the same function M, but instead of doing it in the whole space this program finds this function along specific radio or ray paths. The output will be ready to be used in the data-plotter. The function M is:

$$M = H \cos \phi \sec i$$

which is used in deducing the electron distribution from faraday fading found in radio records from artificial satellites.

The magnetic field H is calculated as a triple series with 6 terms in each variable.

1532 Digital Computer Laboratory. Numerical Quadrature in 2 or More Dimensions. A set of formulas approximating $\int_{-n}^{n} \int_{-n}^{n} f(x,y)\, dx\, dy$ are to be tested for various functions $f(x,y)$. These formulas are of the form $\sum_{r,s} A_{r,s} f(x_r, y_s)$ where $A_{r,s}$ are independent of $f(x,y)$. In order to determine their full accuracy, double precision arithmetic will undoubtedly have to be used later in the study. Initially, however, single precision fixed point will suffice.

1533 Psychology. Second Order Structure in Motivation. Second order structure seems to be extremely sensitive to correlations between first order factors. This study utilizing motivational data which are on hand will be directed toward comparing second order factors obtained from several comparable processes but which yield slightly different primary factor structures. At the same time certain substantive results will be sought which will give greater insight into motivation in children.

First order correlation patterns of motivation factors and of motivation components will be factor analyzed for second order structure. Other patterns from earlier primary factor rotation will also be compared with each other by the patene similarity coefficient.

1534 Psychology. Analysis of Social Structure. In this study sociometric data gathered from 30 classrooms in Houston, Texas will be studied for structure using factor analysis of relationships as a basis (factor analysis has not been used in this way before). The social grouping of the subjects is then compared to personality and life data by means of correlating factor scores and scores on personality tests, achievement tests, and teacher's ratings.

An auxiliary study will be made to test the validity of a model relating personality variables to sociometric behavior. This will involve correlating certain synthesized sociometric scores with selected variables from the 16 P.F. test.

Since 30 different factor analyses would be excessive, only 4 analyses of representative groups will be used at this stage.

1535 Theoretical and Applied Mechanics. Friction Damping. This is subsidiary to the PADA problem under Problem Number 1302. It was there assumed that the dissipative mechanism in the vibratory system was viscous damping. Here the effects on the motion of the system will be investigated if an equivalent amount of energy is dissipated through coulomb damping. The system is simplified to a rotating unbalanced disc and the maximum amplitude of the motion of the center of gravity is computed in each case. These are compared for various values of the parameters.

1536 Aeronautical Engineering. Chemical Equilibria. A class problem in Aeronautical Engineering 431 requires determination of the equilibrium composition of a system for a number of values of three parameters, α_k , k = 1, 2, 3. To find the equilibrium composition it is necessary to solve the nonlinear system

(1) $f_i(\bar{x}_j; \alpha_k) = 0 \qquad i, j = 1, 2, \ldots, n$

for the equilibrium values of the mole fractions, $\bar{x}_j$.

(2) Let $S = \sum_i |f_i(x_j; \alpha_k)|$.

The solution of (1) will be obtained by minimizing S in Equation (2), using H-6 and a faster subroutine than that used for Problem 1266.

1537 Institute of Communications Research. Attitudes of General Medical Practitioners Concerning Mental Illness. A survey has been made of 431 general medical practitioners, randomly selected from the entire United States.

The survey included three types of questions: (1) information; age, treatment of mental illness, percentage of referrals to psychiatrists, etc.; (2) opinions; their degree of agreement to stated opinions such as "Nervous breakdowns seldom have a physical origin"; and (3) attitudes; their attitudes toward such mental health concepts as Neurotic Person, Psychiatrist, etc. The interrelationships among 70 of these items is to be investigated. In particular, we wish to investigate the relations between age, whether or not mental illness is treated, and the attitudes of the general practitioners toward mental illness. The Illiac will be used to obtain the matrix of intercorrelations for these 70 variables.

Table I shows the distribution of Illiac machine time for the month of October.

TABLE I

	Hrs:Min	
Regular Maintenance	97:15	
Unscheduled Maintenance	11:10	
Drum Engineering	11:34	
R.A.R.	:42	
Leapfrog	3:28	
Wasted	:15	
Library Development	2:25	
		126:49
Use by Departments		
Classes	6:47	
Agricultural Economics	2:20	
Agronomy	9:58	
Animal Science	6:26	
Astronomy	6:22	
Bur. Educational and Business Research	:12	
Bureau of Educational Research	22:51	
Chemistry (AEC AT(11-1)691)	49:23	
Chemistry (NSFG-7336)	3:26	
Chemistry (Nonr-83443)	:29	
Chemistry	35:23	
Coordinated Science Laboratory	56:58	
Electrical Engineering (NSFG-7421)	1:31	
Electrical Engineering (AF 33(616)-6079)	1:09	
Electrical Engineering (NASA-NSG 24-59)	1:33	
Electrical Engineering	2:15	
Education (44-20-70-312)	2:20	
Education	7:41	
Economics (NSF G-7056)	7:59	
Economics	:37	

(continued on next page)

TABLE I

Use by Departments (continued)

	Hrs:Min		
Digital Computer Laboratory (AEC AT(11-1)415)	5:10		
Digital Computer Laboratory (NSF G-9503)	2:13		
Digital Computer Laboratory	35:43		
Physics (AF 529)	:04		
Physics (Nonr 1834(12))	1:08		
Physics	38:31		
Stanford Research Institute	4:28		
Music	:03		
Psychology (Nonr 1834(11))	:37		
Psychology (1715)	13:26		
Psychology (AF 49(638)371)	1:49		
Psychology (NIH M-2331 Act. 7289)	1:24		
Psychology (SAE 8383)	1:24		
Psychology	35:15		
Theoretical and Applied Mechanics (USPHS M2509)	:38		
Theoretical and Applied Mechanics	:51		
State Water Survey (DA 36-039 SC 75055)	:40		
State Water Survey	:58		
Mechanical Engineering (DA-11-022-ORD-1980)	:04		
Mechanical Engineering	4:32		
Structural Research (AASHO Road Test)	4:45		
Structural Research (AF-464)	:04		
Structural Research (Nonr 1834(03))	:18		
Structural Research	43:04		
Marketing (1507)	:27		
Student Counciling	:30		
Institute of Commercial Research	:36		
Botany - Eastern Illinois University	1:53		
Mining and Metallurgical Eng. (AF 6770)	:12		
Zoology	:09		
		426:36	
			553:25

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 10:30 a.m. Since the periods between 7 a.m. and 10:30 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance, and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures

frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for October.

TABLE III

Reader		3
Punch		2
Arithmetic		1
Control		4
Drum		7
Scope		3
Power		2
Unknown		6
	Total	28

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUP-TIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
10/1/59	20:02	:00	3:58	0		0	:00	0
10/2/59	19:45	:01	4:14	1	(1) Reader "G" tore tape	0	:15	0
10/5/59	21:05	:27	2:28	1	(1) Drum failure	0	:35	0
10/6/59	19:39	:00	4:21	0		0	:09	0
10/7/59	19:25	:03	4:32	1	(1) Punch "5" failure	0	:00	0
10/8/59	20:25	:15	3:20	1	(1) Unknown	0	:00	0
10/9/59	19:57	:36	3:27	2	(1)(2) Drum Failure	0	:00	0
10/12/59	19:18	:00	4:42	0		0	:00	0
10/13/59	20:14	:07	3:39	2	(1) Camera inoperable (2) Light on reader G out	0	:00	0
10/14/59	20:42	:00	3:18	0		0	:21	0
10/15/59	18:08	2:07	3:45	5	(1) Unknown (2-4) White switch failure (5) Camera inoperable	0	:00	0
10/16/59	17:39	2:45	3:36	3	(1) Punch #4 failed (2) Scope inoperable (3) D.C. power in Illiac off	0	:17	0
10/19/59	19:55	:00	4:05	0		0	:00	0
10/20/59	21:35	:01	2:24	1	(1) Unknown	0	:00	0
10/21/59	17:11	3:49	3:00	7	(1-2) Unknown (3-6) Drum failure (7) Filament voltages too high	0	:16	1
10/22/59	18:40	1:19	4:00	2	(1) Arithmetic error (2) White switch failure	0	:30	0
10/23/59	20:48	:00	3:12	0		0	:00	0
10/26/59	20:55	:01	3:04	1	(1) Unknown	0	:00	0
10/27/59	21:15	:00	2:45	0		0	:00	0

TABLE II (Cont'd.)

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
10/28/59	20:00	:00	4:00	0		0	:29	0
10/29/59	20:20	:00	3:40	0		0	:21	0
10/30/59	21:25	:01	2:34	1	(1) Reader "I" tore tape	0	:00	0
TOTALS	438:23	11:32	78:04	28		0	3:13	1

PART IV
IBM 650 USE AND OPERATION

New 650 Codes

During the month of October three new programs were added to the Digital Computer Laboratory IBM 650 Library.

D3'-53' "Snapshot" Trace Routine Using 407 On Line. This checking routine permits the user to specify a list of blocked locations in the program under test. The program is operated at full speed until one of these blocked locations is encountered. At each such encounter the contents of the distributor, the accumulators, and the index registers prior to execution of the blocked instruction will be printed. As an optional feature a set of memory locations can be printed at each such encounter.

(M. Gray)

X8'-54' Random Card Layout Unpacking Routine. This routine enables randomly spaced positive data to be unpacked from cards and placed on one of the magnetic tapes.

(L. Matsunaga)

K1'-55' D - Squared Statistic Program. This routine computes the D-squared statistic which is generally used to compare score sets, or profiles, and is defined as the sum of the squares of the individual variates. Standard deviations, sums of squares, and means of the scores will also be computed. This program exists in two versions. One takes its input data directly from cards. The other takes its data from one of the magnetic tape units.

(L. Matsunaga)

IBM 650 Usage

During the month of October specifications were presented for 5 new problems. This list does not indicate how the IBM 650 was used because large amounts of machine time may have been consumed by problems with numbers less than 51'. Numbers followed by T are for theses.

51' Statistical Service Unit. Chi-Square Table. This is a program to prepare a special table that is used to simplify the calculation of Chi-Squares on desk calculators.

52' Bureau of Educational Research. High School Testing. The 650 will be used to convert raw scores of 10 tests into deciles. Approximately 60,000 to 70,000 high school students will receive these tests each year.

53'T Marketing. A Comparison of Projective and Non-Projective Techniques in Marketing Research. Six questions are included in the experimental section of this survey. A sample of 300 persons was interviewed, and the sample was divided into two matched groups. One group was asked the six experimental questions using a pictorial projective technique. The other group was asked the same questions in open-end (non-projective) form.

Hence, two bodies of data have been produced. These groups of data will be compared along various dimensions to ascertain whether either interviewing method produces different results. One dimension simply is comparison of incidence within response categories. Chi square analysis will be applied to indicate whether significant differences exist. Interviewers rated respondents on the defensiveness they manifested during the interviewing session. Frequencies of defensiveness scores have been produced for each sample half. These frequencies also will be compared by chi square analysis to ascertain whether either interviewing method produces significantly different defensiveness scores. Responses also are being compared to indicate whether either interviewing method produces a greater variety of answers. Frequencies of variety scores will be compared by chi square analysis to test the significance of any observed variations.

In summary, the 650 machine will be employed to: (1) tabulate response frequencies for all survey questions; (2) produce frequencies for cross tabulation of survey data by population attributes; (3) compare the two bodies of

survey data by chi square analysis along several basic dimensions to ascertain whether either interviewing method under study is more effective than the other in marketing research; and (4) calculate the significance of variations produced by cross tabulation using chi square analysis. The tabulation program and chi square analysis program will be employed.

54' Digital Computer Laboratory. Floating Point Quadrature with Reduced Round-Off Error. Evaluation of a quadrature formula requires a summation of the form

$$S = \sum_{i=0}^{N} c_i f_i$$

where c_i are constant coefficients, f_i is the value of the integrand at the i^{th} integration step, and N is the number of integration steps. When this sum is performed in floating point arithmetic it will generally reduce the round-off error if the summation is performed in $\log_2 N$ steps, according to the prescription

(a) Sum pairs: $S_{p_1} = c_1 f_1 + c_2 f_2,\ S_{p_3} = c_3 f_3 + c_4 f_4, \ldots$

(b) Sum quartets: $S_{q_1} = S_{p_1} + S_{p_3},\ S_{q_5} = S_{p_5} + S_{p_7}, \ldots$

(c) Sum octets: . . . .

etc., until finally on the last step the complete sum is obtained.

The advantages of this scheme will be tested by applying it to a number of examples.

55' Physics. Resonance Integral Approximation. This is a calculation peripheral to a Monte Carlo resonance calculation on ILLIAC. The reason for using the 650 is that the numeric integration to check the ILLIAC code requires a great deal of input and very little computation.

In hydrogen-uranium systems, for one resonance,

$$P = e^{I} \frac{E}{E_F}, \quad I = \frac{\sigma_s^H}{\sigma_0} \frac{N^H}{N^u} \int_E^{E_F} \frac{dE'}{E'} \frac{1}{\psi(E_1T) + \beta}$$

$$\beta = \frac{1}{\sigma_0} [\sigma^u_{pot} + (\sigma_a^H + \sigma_s^H) \frac{N^H}{N^u}]$$

$$\sigma_0 = 4\pi(\frac{A_g \Gamma_n}{E_0 \Gamma} + R'^2)$$

and $\psi(E_1T)$ is the (doppler) resonance broadening function.

Table I' shows the distribution of the IBM 650 machine time for the month of October.

TABLE I'

	Hrs:Min		
Regular Maintenance	16:29		
Unscheduled Engineering	15:52		
Air Conditioning Maintenance	10:26		
Library Development - D.C.L.	10:16		
Library Development - C.S.L.	2:06		
Demonstrations	:36		
Log Summation	:53		
Mathematics 395	2:02		
Wasted	56:31		
		115:11	
Use by Departments			
Statistical Service Unit	57:29		
Theoretical and Applied Mechanics	1:14		
Civil Engineering	23:15		
Agronomy	1:20		
Physics	3:23		
Agricultural Extension	1:44		
Digital Computer Laboratory	1:03		
Caterpillar - Decatur, Illinois	5:35		
		95:03	
			210:14

Error Frequency and Analysis

The IBM 650 is normally on from 8 a.m. to 5 p.m. The machine is used for preventive maintenance from 8 a.m. to 12 noon on Wednesdays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for October.

TABLE III'

533	2
650	6
Floating Point	5
407	3
Tape Unit	1
Air Conditioning	3
Unknown	2
Total	22

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
10/1/59	6:54			2:06	0		
10/2/59	8:11			:49	0		
10/5/59	6:10			2:50	0		
10/6/59	11:33			3:02	7		(1) 533 punched cards on a slant (2-7) Loose wire on 650
10/7/59	9:20	4:00		:15	0		
10/8/59	6:17			2:48	0		
10/9/59	4:13		:07	4:40	0		Suspect floating point
10/12/59	3:04		:40	5:16	1		Suspect floating point
10/13/59	2:53			6:07	0		
10/14/59	:49	3:55		:05	2	4:11	(1)(2) Air conditioning out
10/15/59	3:12	:38		:15	1	6:15	Air conditioning out
10/16/59	3:13			5:47	0		
10/19/59	5:43			3:17	0		
10/20/59	5:44			3:33	0		
10/21/59	:43	3:56	1:37	2:44	3		(1)(2)(3) Bad tube in 407
10/22/59	6:29		:50	1:41	4		(1) Light rewind not adjusted (2) Incorrect program (3)(4) Suspect floating point
10/23/59	5:09			3:51	0		
10/26/59	2:30			6:32	1		Suspect floating point
10/27/59	6:27		2:28	:05	2		(1) Floating point (2) Unknown
10/28/59		4:00	5:00		0		Checking for floating point trouble

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
10/29/59	7:19		1:26	:15	1		Floating point trouble
10/30/59	5:03		3:44	:33	0		Floating point trouble
TOTALS	110:56	16:29	15:52	56:31	22	10:26	

PART V

GENERAL LABORATORY INFORMATION

Seminars

"Transistorized Computers in Japan", by Dr. S. Takahashi, Electrotechnical Laboratory, Tokyo, Japan, October 5, 1959

"Quadrature Over a Square and Over a Hypercube", by Dr. J. C. P. Miller, Visiting Professor, University Mathematical Laboratory, Cambridge, England, October 12, 1959

"A New ILLIAC Routine for the Computation of the Static Equilibrium Voltages and Currents in a Circuit with Non-Linear Elements", by Dr. Lloyd D. Fosdick, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, October 19, 1959

"Factor Analysis: The Scientific Question, The Mathematical Model, Computational Problems", by Dr. Henry F. Kaiser, Bureau of Educational Research, University of Illinois, Urbana, Illinois, October 26, 1959

Personnel

The personnel associated with the department and, hence, the contributors to this report are:

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Baur, John W., 1/2-time Research Assistant
Blankfield, Mrs. Judith, Research Associate
Blencoe, Robert W., Computer Operator I
Bowes, Mrs. Doris E., 1/2-time Research Assistant
Brearley, Harrington C., Jr., Research Asst. Prof. of Elec. Eng.
Briley, Bruce E., 1/2-time Research Assistant
Briley, Mrs. Marilyn J., Clerk-Typist II (Started Oct. 13)
Carter, Clifford E., Electronics Engineer
Clark, Miss Helen B., Secretary
Coady, Robert F., Electronics Technican II for Illiac (Started Oct. 5)
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Field, William L., 1/2-time Research Assistant
Fileccia, John L., Electronics Technician I
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Flenner, Ross H., 1/2-time Research Assistant
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Foster, Merlin J., Computer Operator I
Foulk, Clinton R., 1/2-time Research Assistant
Frazer, W. Donald, 1/2-time Research Assistant
Gear, Charles W., 3/4-time Research Assistant
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Guckel, Henry, 3/4-time Research Assistant
Gustafson, Ronald A., Electronics Technician I

Huffman, W. Logan, Computer Operator II
Irwin, Arlyle F., Electronics Technician I
Johnson, Noel H., 3/4-time Research Assistant
Kerkering, Thomas E., Sr. Laboratory Mechanic
Kimbrough, Mrs Lynn, Keypunch Operator I
Krabbe, Shirlie P., Electronics Technician II for Illiac
Kunihiro, Toshiro, 1/2-time Research Assistant
Lacy, Donald L., 1/2-time Teaching Assistant
Leslie, James D., 1/2-time Research Assistant
Liu, Chao-ning, 1/2-time Research Assistant
Lopeman, Harold E., Electronics Engineer
Meagher, R. E., Head of the Laboratory (on leave beg. April 1, 1959)
Metze, Gernot A., Research Asst. Professor
Michael, George W., Administrative Assistant
Miller, J. C. P., Visiting Professor
Muerle, John L., 3/4-time Research Assistant
Muller, David E., Res. Assoc. Prof. of Appl. Math.
Murrell, T. A., Assoc. Prof. of Elec. Eng.
Naikelis, U. Stanley, 1/2-time Teaching Assistant
Oare, John W., Draftsman
Peek, Levin J., 1/2-time Research Assistant
Pelg, Edmund, Electronics Technician II for Illiac
Penhollow, John O., 1/2-time Research Assistant
Penny, Samuel J., 1/2-time Research Assistant
Piper, Thomas C., 1/2-time Research Assistant
Poppelbaum, W. J., Res. Assoc. Prof. of Elec. Eng.
Raff, Mrs. Murna J., 1/2-time Teaching Assistant
Ray, Sylvian R., 3/4-time Research Assistant
Reeves, Artie L., Electronics Technician I
Resh, James A., 1/2-time Research Assistant
Richardson, Warren V., Tape Equipment Technician I
Rittis, James A., Draftsman
Rivera, Ralph M., Jr. Laboratory Mechanic
Robertson, James E., Research Professor of Elec. Eng.
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Rudman, Mrs. Linda G., Tabulating Machine Operator I
Russell, Miss Ramona J., Computer Operator II
Saathoff, Miss Norma I., Computer Teletype Operator
Serio, Frank P., Electronics Technician II
Shively, Richard R., 1/2-time Research Assistant
Snyder, James N., Research Professor of Physics
Sullivan, John D., Electronics Technician II
Swartwout, Robert E., 3/4-time Research Assistant
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Trnka, Mrs. Pauline, Clerk-Stenographer II
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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

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PART II - CIRCUIT RESEARCH PROGRAM
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November, 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

A) Logical Design

1. Main Arithmetic Unit End Connections

Drawings of all special connections in the $A_{40}(S_{40})$ to $Q_4(R_4)$ area have been completed in detail, together with a block diagram of data flow.

Selector connections for the other extremities of A and Q, reflecting the latest instruction code definition available, are in progress. In preparing such end connections, the following mode-of-operation signals are postulated:

(a) E. S. EXTENT OF SHIFT = 1/0 if SHORT/LONG
("SHORT" only most significant half of double length accumulator is involved.)

(b) T.S. TYPE OF SHIFT = 1/0 if CYCLIC/ARITHMETIC

(c) Q.S.C. Q sign correction; conditions 4 bit subtractor at low end of Q

(d) R.S.C. R sign correction

(e) D.S. DIRECTION OF SHIFT = 1/0 if RIGHT/LEFT

(f) W.R. WORKING REGISTER; = 1/0 if number of interest is in SR/AQ

(Q.S.C. and R.S.C. replace, in part, the functional definition of Q_{46}* and R_{46}* given in Report 92.)

In the general case, signals (a) to (e) are dependent both on the order being executed and the range of data involved.

(R. R. Shively)

2. Main Arithmetic Unit Division Predictor

November was devoted to the designing of most of the division prediction logic. The basic design of the assimilator, comparators and decode logic has been completed, but the problem of completion signals for these circuits has not been entirely solved. The one major block of logic that has not been

designed is the three-halves circuit for the approximated divisor. A speed-independent design of this circuit is currently under study.

(John O. Penhollow)

3. Floating Point Addition

A complete up-to-date description of floating point addition, as described by Wheeler (Report 92) has been maintained and is ready for use in the design of the Exponent Arithmetic Unit and the controls.

(A. Avizienis)

4. Exponent Arithmetic Unit (EAU) Design

Several changes and corrections were introduced as a result of study of the tentative order code. The problem of parallel operation on two successive instructions was raised; no final recommendation exists now. The design of a speed-independent adder for EAU was begun.

(A. Avizienis)

5. Control Design

As a prelude to the design of the new computer's control systems, a typical subcontrol will be designed, proved out, and (hopefully) built and tested. It is felt that data from this subcontrol will supplement the information obtained from the control systems for Test Unit #2. In an effort to make this subcontrol typical, the logical diagram was synthesized from a change chart which in turn was chosen so that the anticipated operations indicated below would be included.

a. Several gates must operate concurrently.

b. Parallel gate paths will operate conditionally. That is, the desired path will be indicated by some external signal.

c. One gate shall be operated more than once during a cycle by separate control logic.

d. Parallel gate paths will be recombined into one path both from concurrent operation and from conditional operation.

The change chart has been established, the logical diagram has been drawn, and the circuit has been tested out with several runs on Q-5. To date these tests indicate that the operations (a),(b),and (c) above are apparently correctly synthesized, however, the recombination circuitry is not as yet speed independent.

(R. E. Swartwout)

B) Circuit Design and Layout

In the process of preparing chassis drawings for the main arithmetic unit, the need for additional work on the basic circuits became apparent. Efforts will be concentrated on bringing the basic circuit drawings up to date.

(C. E. Carter
H. E. Lopeman)

C) Core Storage Unit

1. General Status

During November, the organization of the core memory has been considered in more detail and a new logic diagram has been prepared. The task of generally "tidying up" minor details of circuits and logic has also been pursued. This has led to the design and testing of specialized types of logic drivers which provide more economy in the memory's peripheral logic.

(S. Ray)

2. Address Decoder

The logic and circuit design for the address decoder are essentially completed and a test circuit is soon to be built.

(B. Briley)

3. Digit Lines

A theoretical study to determine what causes the oscillations on the digit line at rewrite has been initiated.

(J. D. Leslie)

D) Input-Output and Auxiliary Storage

The input-output and auxiliary storage equipment to be provided when the new computer is first operated is as follows:

1. Magnetic tape units (four units, expandable to eight if needed)
2. Magnetic drum
3. Paper tape reader and punch.

Initially, input to the computer will be from the high speed paper tape reader. Later, as the input volume increases, the effective input rate will be increased by off-line operation of the paper tape reader, followed by

speed conversion using the magnetic tape units. Time sharing and speed conversion schemes will be used for output.

When the computer is first operated, the magnetic tape units will be used principally for auxiliary storage, and will operate only at high speed, about 150 inches per second. Slow speed operation will not be used until later when the off-line equipment is built. The magnetic tape units will also be used when a long problem is to be run in installments. In this case, the contents of the computer will be recorded on a magnetic tape at the end of one installment. This tape will then be removed from the tape unit, and stored until time to run the next installment. The tape unit used for this "between-installments" storage may operate at a lower packing density than the other units.

(H. C. Brearley)

We have been unable to eliminate tape slippage on the Ampex FR-300 Magnetic Tape Unit even with the new vacuum chambers and various adjustments of the tape rollers and guide posts. Ampex has advised us that they have a new initial adjustment procedure which may help us with the slippage problem. A complete redesign of the FR-300 servo system is being undertaken by Ampex. They are also considering other modifications such as a system of guide arms which will exert pressure on the tape as it is wound on the reels to insure that all possible air has been forced from between successive layers of tape.

(L. J. Peek, Jr.)

Single channel dropout data was taken on the Ampex FR-300 Magnetic Tape Unit. The tests were performed at a tape speed of 150 inches/second, and a packing density of 600 bits/inch, using Ampex C-1 tape. It was found that groups of one or more bits were lost at approximately 300 locations per channel per 3600 foot reel, except for the outer two channels where the rate was approximately twice as great. Circuits are now being modified and designed for counting the number of individual bits lost, instead of only counting the number of groups.

(C. N. Liu)

A multiple transverse dropout is the loss of more than one bit from a row of 16 bits across the width of the tape. The frequency of such dropouts will determine how complex the error-correcting code must be in order to obtain reasonable intervals of error-free operation. To collect multiple

transverse dropout statistics on the FR-300 Magnetic Tape Unit, an eight channel detector is being constructed. This circuit will produce three output signals, corresponding to the loss of one, two, or more than two bits from the eight channels.

(T. C. Piper)

The study of the mechanical and electrical tolerances which limit the packing density of the magnetic tape recording system has continued. It is hoped that this study will confirm the maximum performance figures supplied by the manufacturer. It will also point out the contribution to this limitation of each variable, some of which may be subject to our control. This information will be used in evaluating the present magnetic tape unit, and in developing specifications and acceptance tests for future units.

(R. L. Cummins)

E) Test Unit No. 1

During November, Test Unit No. 1 ran continuously, except for two voluntary interruptions to substitute a number of new transistors on a trial basis.

(C. E. Carter
H. E. Lopeman)

F) General Organization

Information transferred between the core memory and either the magnetic drum or magnetic tape units will be by 256-word blocks. On tapes, the space between successive blocks should be a small fraction of the block length in order to maintain a high input-output rate and a large capacity per reel of tape. For the magnetic drum, slightly different considerations apply. The gap between blocks is small, but information not read in one drum revolution is not available again for an entire drum revolution, so there is an advantage in reading a large number of words at a time. Since the core memory is used as a buffer during block transfers, the block size should not be so large that a considerable fraction of the core memory is tied up during transfers.

For simplicity in addressing, a block in the core memory will always begin at an address which is a multiple of 256. This has the further advantage that the first five bits of the transfer address may be used to define the block and prevent any references to words in that block by advanced control.

Additional input-output devices may be added to this system by adding an address register for the block transfer and a full or partial word register for each added device. As a simple example, a paper tape input instruction could cause 256 characters, one per word, to be read into a block in the core memory, concurrent with calculation. The buffer register would then be only 7 bits long. Therefore, under program control, the computer can print results of previous calculations, calculate, and input data for future problems.

(C. W. Gear
D. B. Gillies
J. A. Resh)

PART II

CIRCUIT RESEARCH PROGRAM

This work is supported in part by Contract Nonr-1834(15) of the Office of Naval Research and in part by the University of Illinois.

General Remark

As of November 1, 1959, all the work done under Contract ONR Task 15 will be reported on separately in this second part of the Technical Progress Report under the title "Circuit Research Program". The scope of this work is defined as follows:

In the immediate future, the work will continue to be closely associated with the new computer project, i.e. the work under AEC Contract AT(11-1)-415 (supported by the Atomic Energy Commission and the Office of Naval Research). Specifically, it is proposed that a flow-gating memory be developed. This flow-gating memory is to form an essential part of the new computing machine.

It is also proposed that this work include certain studies associated with the circuits for the new computer whenever the problems involved are of a different and unusual nature.

After the above new computer circuits are completed, research will be carried out on circuits having speeds at least one decimal order of magnitude above the speeds of the new computer project. In particular, tunnel diode circuits in the sub-millimicrosecond region will be investigated.

1. Summary of the November Work

These main problems occupied the group in November:

a) The redesign of the flow-gating system (H. Guckel)
b) The investigation of the transient behavior of transistors (T. Kunihiro)
c) The design of high-powered drivers for $\pm$ 1v swings with 20 mμs rise-times (J. Baur)

2. Flow-Gating

After modifying the specifications of the flow-gating system according to the rules shown below, it was realized that a complete redesign of the circuits would be desirable. It seems to be possible now to lower the

α-requirement of the transistors used in the flipflop from .98 to .96, to raise resistor tolerances from 2% to 3% and, most important of all, to lower the gating-power quite considerably.

Specifications of the Flow Gating System as of November 1, 1959

Unit I.

The unit shall have 14 quarter words of 13 bits each (plus perhaps 1 checking bit). The inputs come from 52 (53) buses connected to level shifters, the input of which swings from at least +2.5v to -2.5v are furnished not more than +2.2 ma and -3.5 ma respectively. The output will be available on 52 (53) buses furnishing swings of at least +2.5v and currents of $\pm$ 3 ma. No provisions shall be made for internal transfer of information between words. The access in read-out (driver and setting of 30 mμsec FF.) will not be more than 100 mμsec. The setting time (driver, FG-FF setting time, the input information being present all the time) shall not be more than 150 mμsec. If no word is in the sending state the output bus will have negative signals on it.

Unit II.

As above, except that n (< 16) quarter words are used and no checking bit provisions will be made to compare the first five bits of every quarter word continuously with 5 bits stored in a register.

Unit III.

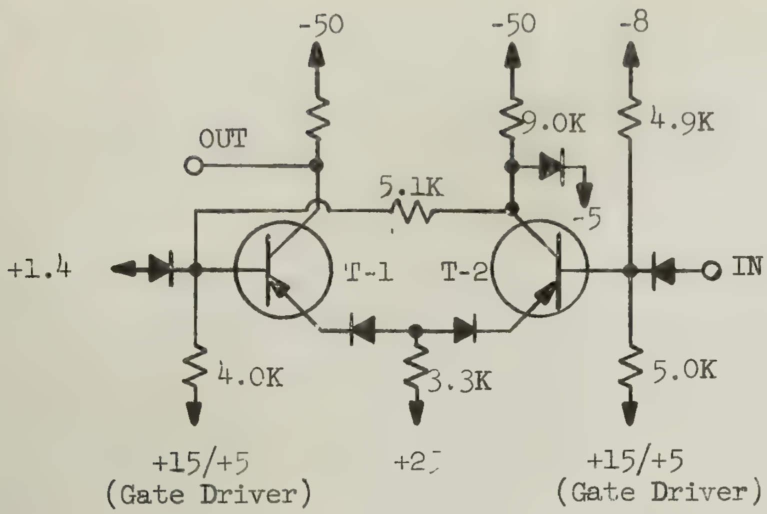
As above, i.e. m (< 16) whole words with up to 4 checking bits (1 per quarter word). Some of the inputs will not be connected to the input buses and some of the outputs will not be connected to the output buses. If coax should be driven, emitter followers will have to be used.

New Flow-Gating Flipflop

A flow-gating flipflop with base gating was designed. (See Figure 1). The operation time of the circuit is slow. In the worst case, read-in times are 100 mμsec with perfect drivers. This time is observed when the flipflop acts like a normal flipflop. This should be expected since the impedance level of the circuit is rather high. Capacitor peaking could of course be used. However, use of a capacitor across the 4.0K resistor forces the use of capacitors across both the 5.1K and 5.0K resistor. This in turn means an increase of the driver current.

Resistors ± 3%

P. S. ± 3%



INPUT: +2.5 → + 3.2 v
2.2 ma max

-.6 → -3.2 v
No Current is drawn if neg. level is -2 → -[illegible].2 v

Gate Driver:

+15 ± .5V
6.52 ma max
+5 ± .5V
4.81 ma max
$.96 < \alpha < 1.0$
2N604 (UI)

Figure 1
Base-Gated Flow-Gating Flipflop

The critical design problem of the circuit is the choice of the 5.1K/4.0K bleeder. It is this bleeder which allows optimization of the collector swing and the driver swing. The maximum collector swing is of course determined by the collector reverse voltage. With the 2N 604 transistor, the useful signal swing is about 17.2-5 = 12.2 volts. The GF 45011 transistor allows a swing of only 10 volts. However, the base must move by 6 volts due to either driver or collector swing. This forces the attenuator to have a gain of about 1/2. The impedance level of the divider is set by the loop gain requirement. It again is minimized.

The following points are evident:

1. If a faster flipflop is desired, a transistor having a higher reverse rating is desirable. This will allow lowering of the impedance level and faster driver pull-up conditions.
2. The transistor cut-off frequencies can be increased simultaneously. An increase in cut-off only will gain very little.

The flipflop will not be able to generate standard levels immediately. A shifting network is needed. A possible method would involve using another 2N 604, i.e. a three transistor flipflop is needed. Since one 2N 604 does

not cost much more than 2 diodes, such a solution is quite possible. The proposed output circuit would then look as follows:

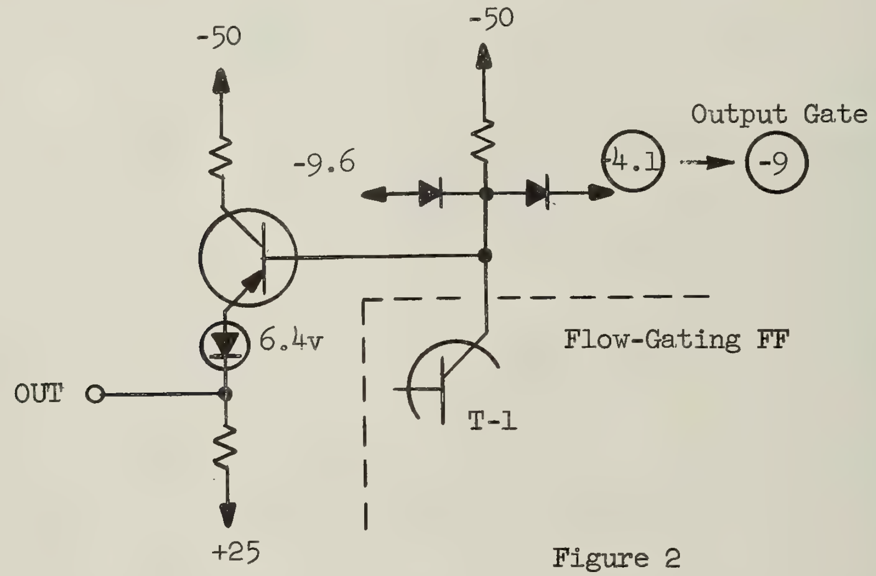


Figure 2
Read-Out Circuit for a Flow-Gating Flipflop

This is very favorable to the send-gating process. The levels can, of course, be adjusted by changing zener potentials. The available output current can be as high as 10 ma. Long-cable driving is now also possible.

An alternate method of flipflop design would involve shifting the input level. It may be possible that the collector can then be brought to standard levels directly. However, this does not mean that speed improvements can be made, and the driving requirements may become worse.

3. Transistor Transients.

A general investigation of the transient behavior and the nonlinearities encountered in static switching of transition was begun. It turned out that both gain A and switching time T are very nonlinear functions of the emitter, base and collector load while the inverse gain bandwidth $k = T/A$ is linear function of these parameters over a wide range of operating conditions. Details of this investigation will be in the next Technical Progress Report.

As a side line to this study, the operation of transistors in the avalanche mode was examined. The preliminary results are as follows:

(i) the high dc alpha transistors show the avalanche mode of operation with lower collector voltages than those for the low dc alpha transistors.

(ii) the base impedances accelerate the avalanche mode operation.

(iii) the switching speed in the saturation region only is as fast as that in the normal mode.

4. High Power Drivers

The 18-bit F-element push-pull driver with the Zener diode input circuit was checked for output capabilities. The procedure consisted of static calculations. All values were computed using a slide rule and static curves. The results indicate an error in the output capabilities as predicted on the circuit diagram S-873. A new design was made.

Static calculations were made on the 250-base drive circuit. The circuit was found to have an error in the output circuit. A low value of resistance on the output lead hampered the drivers' capability to supply the desired load current of 300 ma. Here again the design was corrected. Experiments are now in progress to determine the dynamic behavior of this driver. It is felt that the decoupling problems for the switching-diode supply of the output stage will be a major source of worry.

PART III

MATHEMATICAL METHODS

1. Reduction of Roundoff Error in Floating Point Quadrature (Supported in part by the Office of Naval Research under Contract Nonr-1834(27)).

In general the formula for the numerical evaluation of

$$F = \int_A^B f(x)\,dx \,, \tag{1}$$

has the form

$$F \cong \sum_{i=0}^{N} \alpha_i \, f(x_i) \,. \tag{2}$$

When the arithmetic of Equation (2) is done in floating point a difficulty peculiar to this kind of arithmetic arises. This difficulty is illustrated most forcefully when the integrand is taken to be everywhere positive. Assuming that the sum in Equation (2) is formed by the iterative process

$$\begin{aligned} F_0 &= 0 \,, \\ F_{i+1} &= F_i + \alpha_{i+1} \, f(x_{i+1}) \,, \end{aligned} \tag{3}$$

then as F increases in magnitude the smaller term $\alpha_{i+1} \, f(x_{i+1})$ gets treated less and less accurately as i increases. The fractional part of $\alpha_{i+1} \, f(x_{i+1})$ must be shifted farther and farther to the right, with a consequent loss in the low order digits, to perform the floating point addition $F_i + \alpha_{i+1} \, f(x_{i+1})$. The effects of this loss in accuracy can be quite significant. A simple procedure which in many cases will greatly reduce the error caused by this difficulty has been developed and tested.

The loss in digits resulting from the relative scaling performed in the floating point addition of two numbers becomes least when the two numbers become comparable in magnitude. Then if it were possible to form the summation in Equation (2) by first forming pairs of partial sums

$$\begin{aligned} s_0 &= \alpha_0 f(x_0) + \alpha_1 \, f(x_1) \,, \\ s_1 &= \alpha_2 \, f(x_2) + \alpha_3 \, f(x_3) \,, \\ &\vdots \\ s_{N/2} &= \alpha_{N-1} \, f(x_{N-2}) + \alpha_N \, f(x_{N-1}) \,, \end{aligned}$$

then, combining these in a similar fashion to form partial sums involving four terms, and so forth, it is to be expected that the numbers being added will frequently tend to be of the same order in magnitude, thus reducing the scaling error. A little consideration will show that only $\log_2 N$ storage locations will be necessary to hold the partial sums. Hence the additional storage required by this method, although larger than that required by the usual scheme, is not excessive. In order to compare the relative accuracy of results obtained by this new strategy (call it Method II) with those obtained by the usual method (call it Method I) we have programmed the two methods in floating point for the IBM 650 using Simpson's rule.

A number of tests have been performed and a complete report of this work will be presented later. Some of the more interesting results follow:

Test I:

$$\text{Evaluate } I = \int_0^1 \frac{dx}{x^2-4} .$$

Method I		Method II	
No. of integration steps = N	Error = ϵ	N	ϵ
50	2.2×10^{-3}	10	80×10^{-8}
100	1.1×10^{-3}	50	$< 10^{-8}$
200	0.55×10^{-3}		
500	0.22×10^{-3}		
1000	0.11×10^{-3}		

The error in Method I is approximately 10^5 times as large as the error in Method II. The error in Method I is not reduced significantly by increasing N.

Test II:

The integration in Test I was performed with the independent variable running $0 \to 1.9$ and also for $1.9 \to 0$. The two results agreed exactly. It is not difficult to see that Method II gives a result which is independent, or almost independent of the direction of integration: the independence is complete if $N = 2^p$ where p is a positive integer.

Test III:

$$\text{Evaluate } I = \int_0^2 (x-1)^3\, dx \equiv 0.$$

Here the Simpson's Rule summation error is zero. Method II gives a result which is precisely zero for N = 10, 50, 100, 1000. Method I has not yet been done for this, but it can be expected to be worse.

Test IV:

In Test III the symmetry of the function about $x = 1$ is especially advantageous for Method II. To destroy this advantage we evaluated

$$I = \int_0^B (x-1)^3 \, dx$$

for a range of values of B on the interval $1 \leq B \leq 2$. In every case the result was not in error by more than one unit in the least significant digit of the fractional part of the floating point number; N was equal to 50, and it could probably be reduced considerably without affecting this result.

The fundamental idea of Method II is obviously quite generally applicable to a variety of problems. It is in numerical quadrature that it is especially effective.

(L. D. Fosdick)

2. Thickness of Shocks (Supported in part by the National Science Foundation under Grant G9503.)

The reasons for referring to the "thickness" of a shock have been examined closely.

The one dimensional shock has an equation of the form

$$x = a(v_1 \log (v_0 - v) - v_0 \log (v - v_1))$$

and the limiting values v_0 and v_1 are assumed only at $x = \pm \infty$. If we approximate v (and other physical variables) as

$$\begin{array}{ll} v = v_0 & x \leq 0 \\ v = v_1 & x \geq \Delta \\ v = f_n(x) & 0 \leq x \leq \Delta \end{array}$$

so that v is continuous, and Δ is the "thickness" of the shock, then we may demand that the four equations of conservation are obeyed at a number of points depending on the freedom of choice of the $f_n(x)$, so that the maximum error of the conservation equations is minimized with respect to the choice of $f_n(x)$ and Δ. In the former case, if $f_n(x)$ is a polynomial of degree n such that

$f_n(0) = v_0$ $f_n(\triangle) = v_1$ then as $n \to \infty$, $\triangle \to \infty$ as $f_n(x) \to v(x)$ the correct solution. This is probably true for a minimum method. For the first approximation we find in both cases that

$$\triangle = \frac{bw[v]}{[p]}$$

where b is a constant, w the viscosity, and $[v] = v_1 - v_0$.

This incidentally is the form of the result when any particular percentile point is taken on the velocity function to determine the boundary of the shock. In the two dimensional case we may use analogous methods to determine the thickness of the shock and hence the flow variables either side of it. The study of the slip-stream appears to be different. First there is no one-dimensional slip-stream as a first approximation and secondly the thickness of the slip-stream may not be $O(w)$ as $w \to 0$, for if it were then the Reynolds' number would be $O(1)$, but in order that in the limit we get non-viscous flow we must have $R \to \infty$.

(C. W. Gear)

3. Einstein Field Equations (Supported in part by the National Science Foundation under Grant G9503.)

Calculations were redone for the classical case; i.e., for small values of the parameter u_c (see Technical Progress Report, May 1958) with the equation of state of a relativistic gas. The values obtained substantially agreed with those obtained previously.

(J. Blankfield)

PART IV

SWITCHING CIRCUIT THEORY

1. Codes for Correcting Errors in Adjacent Bits of a Message (Supported in part by the Office of Naval Research under Contract Nonr-1834(27)).

Group codes may be described by means of a matrix

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} \qquad (1)$$

whose elements a_{ij} are taken from $\{0,1\}$. A coded message $q = (q_1, q_2, ---, q_n)$ is any n-tuple of elements from $\{0,1\}$ satisfying $\sum_{j=1}^{n} a_{ij} q_j = 0$ for all $i = 1, 2, ---, m$, where summation is to be interpreted modulo 2.

If we take the m rows of A as being linearly independent and assume that each column of A can be formed from its predecessor by a non-singular linear transformation T, then we write

$$T \begin{pmatrix} a_{1j} \\ a_{2j} \\ \\ a_{mj} \end{pmatrix} = \begin{pmatrix} a_{1j+1} \\ a_{2j+1} \\ \\ a_{mj+1} \end{pmatrix}. \qquad (2)$$

Here T may be obtained in the form of an m x m matrix, such that

$$a_{ij+1} = \sum_{r=1}^{m} t_{ir} \; a_{rj} \qquad (3)$$

where t_{ir} is an element of T.

Now the condition that the matrix A defines a code which will correct k+1 or fewer errors in adjacent bits is simply that all polynomials in T of the form

$$T^r \, K\,(T) \qquad (4)$$

shall be distinct. Here K(T) is any polynomial of degree no greater than k and r is any integer such that r plus the degree of k is no greater than n-1. Again the coefficient field is taken to be $\{0,1\}$. It is also true that certain conditions must be placed on the initial column of A, but these conditions can easily be satisfied.

The adjacent error-correcting code problem consists of finding a transformation T, given m and k, which will give the largest n. An information-theoretical upper limit for n may be seen to be

$$n \leq 2^{m-k} + k-1, \tag{5}$$

but the requirement that T be linear produces the stronger inequality

$$n \leq 2^{m-k} - 1. \tag{6}$$

This latter bound for n may actually be achieved, however, in many cases and it has been shown that it can always be achieved when k = 0 or k = 1. A systematic approach has been found when k divides m, but the methods used do not actually produce codes in all cases. No universal method is known for the general case, but codes may be found easily in practice.

It is notable that the condition for the matrix A to define a code is an algebraic condition on T. Therefore, any transformation which preserves these properties may be applied to T without affecting its characteristics which are important for our purposes. Therefore we consider T to be of the form

$$T = \begin{pmatrix} S_1 & 1 & 0 & & & \\ S_2 & 0 & 1 & 0 & & 0 \\ S_3 & 0 & 0 & 1 & 0 & \\ & & & 0 & 1 & \\ & & & & & \\ S_m & & 0 & & 0 & 1 \\ & & & & & 0 \end{pmatrix} \tag{7}$$

where $P(x) = x^m + S_1 x^{m-1} + --- + S_m$ is the characteristic equation of the original matrix T.

Let x be a dummy variable and write $a_j(x) = a_{1j} x^{m-1} + a_{2j} x^{m-2} + --- + a_{mj}$. We then have the relationship

$$a_{j+1}(x) \equiv x\, a_j(x) \text{ modulo } P(x) \tag{8}$$

by our two definitions (2) and (7).

We let $a_1(x) = 1$ and condition (4) may be re-expressed as a similar condition involving $x^r K(x)$, modulo $P(x)$.

Thus, we have reduced our problem to the study of polynomials in the coefficient field $\{0, 1\}$. The method for obtaining a code, (by obtaining $P(x)$) consists of finding two irreducible polynomials $P_1(x)$ and $P_2(x)$ of degree m-k and k respectively. Assume x is a primitive root of $P_1(x)$, so that $x^r \equiv 1$

modulo $P_1(x)$ if and only if r is a multiple of $2^{m-k}-1$. Also assume that k divides m. Then let $P(x) = P_1(x)\ P_2(x)$.

This method often yields a maximum efficiency code (by (6)) so that

$$n = 2^{m-k}-1.$$

In case $k = 0$ and $P_2 = 1$ and in case $k = 1$ and $P_2 = x + 1$ it can be shown to always yield a code. For larger k, it may or may not. For example, if $P_1 = x^4 + x^3 + 1$ and $P_2 = x^2 + x + 1$, a code is obtained, but if $P_1 = x^6 + x^5 + x^3 + x^2 + 1$ and $P_2 = x^2 + x + 1$ then no code is obtained. In the latter case, however, more elaborate types of errors are corrected, while simpler types, such as double adjacent errors are not. Present efforts are directed toward finding additional conditions on P_1 and P_2 to ensure that they generate a code.

(C. W. Gear
D. E. Muller)

PART V

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of November one new routine was added to the Illiac Library.

N15-271 Mixed Number Input. This routine inputs mixed numbers. The mixed number consists of a sign, integer, point, fractional part with a carriage return line feed as a terminating symbol. After the input of such a number, the integer part scaled by 2^{-39} appears in A and the fractional part appears in Q.

(J. Blankfield)

Illiac Usage

During the month of November specifications were presented for 23 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1538 T. Numbers followed by T are for theses.

1538 T Psychology and Institute of Communications Research. A Cross-Cultural Analysis of Phonetic Symbolism. A considerable number of previous studies, notably those by Osgood, et al, have demonstrated extensive cross-cultural similarities in the structure of meaning systems for various heterogeneous concepts administered to subjects from diverse culture groups. The results specially indicate that despite obvious and large differences between culture groups with regard to the specific meanings assigned to concepts, the structure of these meaning judgments, i.e., their factorial representation, is very similar. In this particular study, designed to augment the increasing body of data of this kind for a particular aspect as yet uninvestigated, data in the form of auditory sense judgments employing an instrument called the semantic differential was collected on each of 50 nonsense stimuli constructed to conform to specific linguistic criteria. These stimuli were administered to, and data collected from, two diverse language/culture groups.

In order to investigate the degree of relationship between the meaning systems employed by subjects for these stimuli, the factor structures of each of the culture/language groups are to be compared. To this end, ILLIAC programs for intercorrelation and matrix transposition are essential ancillary steps. Subsequent to the raw factor solution, analytic rotation using the Varimax solution is to be performed.

1539 Psychology. Structure of Data Problem. This research problem relates to "Homogeneity" method of cluster analysis.

A program using this method has been written. It is desired to investigate the properties of the program with a view toward publishing a statement of the program and its theoretical implications for the problem of "Structure of Data". This latter problem is now typically solved by the use of an additive, linear model which satisfies certain criteria of goodness of representation. Here reference is made to the various methods of "factor analysis".

The result of the "Homogeneity" program is a partitioning of a set of variables into subsets of homogeneous variables. It is also a linear solution subject to the constraint that all weights must be +1, -1, or 0, and no variable can have a non-zero weight in more than one cluster (subset). Clearly, which solution is to be preferred depends mainly on the underlying structure in the data being analyzed, as well as on various practical considerations. Because of the simplicity of the operations used in the "Homogeneity" program, it can be defined for ordinal as well as metric data, with useful translations of the criteria of goodness of representation. Rank order data are often at hand in social science research, in contrast to metric data, and a method of simplification for such data would be welcome.

The present request is to be used in comparing the results of the two methods of analysis referred to above, namely factor analysis and homogeneity analysis. It is proposed that three of four small matrices of psychological data, including at least one involving rank-order data, be analyzed by the two methods.

1540 T Food Technology. Investigation of the Physical State of the Milk Proteins in Undiluted Skim Milk. The physical state of the milk protein in

their natural environment has not been previously investigated. Techniques have recently been developed in this laboratory for their electrophoretic characterization without disturbing of the system. However, electrophoresis of protein mixtures results in complex patterns, which are assumed to be composites of overlapping, symmetrical and/or asymmetrical Gaussian curves.

An accurate evaluation of the individual curves is important for the characterization and identification of the protein species. So far the patterns have been examined mostly in a qualitative manner and much valuable information has undoubtedly been lost. Therefore, this problem was undertaken to attempt a quantitative evaluation by help of the Illiac.

The problem has been approached in the following manner:

The pattern of an electrophoretic analysis may be described by a set of ordinates. In general it may be assumed that from one to ten components may contribute significantly to the electrophoretic pattern (i.e., more than 1% of the total area). From experience and a qualitative examination of the pattern approximate values may be obtained for: (a) the minimum number of components; (b) the parameters: Y_{max}, μ, δ_1, and δ_2, which characterize these Gaussian distributions. Least squares fitting techniques will be used to determine these parameters.

1541 Psychology. Investigation of Objective Personality Factors in Middle Childhood Range. This study aims to determine correlations among 75 or so objective personality tests (about 140 variables) to be administered to 200 eight year old children to (1) replicate marker tests from previous studies and (2) compare new tests with markers from previous work. Scores are to be brought to normal distribution and correlated by product moment r. Centroid extraction of factors with iterated communalities, tests for completion of extraction, rotation by oblimax, maxplane and oscilloscope, and item analysis are to be carried out.

1542 Psychology. Comparison of British and American Samples of Factor Structure. A comparison of the personality factor structure in British and American students, with special reference to the relation between personality, interests and achievements will be made.

1543 Psychology. Relation of Psychological and Physiological Variables. This study is concerned with factor analysis of combined psychological and physiological matrices, gathered by R- and P-technique, with samples of order 100. The matrices of scores will be correlated, factored by centroid, with iterated communalities, and rotated to simple structure by oblimax, maxplane and oscilloscope.

1544 Psychology. Alignment of Factors from Ratings and Questionnaires. This study, which may develop into a thesis project, is concerned with the problem of "instrument factors" and may require some experiments with physical models, measured and factored. The processes on Illiac, however, will be essentially product moment correlation and centroid factoring, with a good deal of oscilloscope rotation to explore tentative hypotheses.

1545 Psychology. Agreement of Personality Factors in Children Measured in Different Media. Ratings on children's behavior are being compared with questionnaire and objective test measures. Three samples of children, each of order about 100, will each provide three or four score matrices to be centroid factored. Rotation by oblimax and maxplane methods are to be compared.

1546 Psychology. Research on Primary Mental Abilities. This study aims to determine correlations among ten primary abilities with maximum accuracy (1) to get purer brief measures of primaries and (2) to determine second-orders more accurately in relation to "crystallized ability" theory. It requires score and correlation matrices at each of two ages, on fifty variables on 200 people. Scores are to be brought to normal distribution and correlated by product-moment r. Centroid extraction of factors with iteration of communalities, rotation by oblimax, maxplane and oscilloscope will be made.

1547 Psychology. Development of Motivational Analysis Measures for Adults and Children. Measures of attitude strengths by each of four or five devices are being made on each of fifty attitudes for one group of 150 and one of over 200 children. These will be correlated by product moment and factored by centroid, with iteration of communalities, and rotated by oblimax, maxplane and oscilloscope. Estimation of factor scores will be carried out by Hurley program. Calculation of reliabilities of variables and factors by product moment will be made.

1548 Psychology. Research on Factor Analytic Methodology. This study generates random number series and factors them (1) as pure error factors; (2) added to actual model data to determine effects of error on simple structure. It uses product moment r program, centroid and principal components factoring and oblimax and oscilloscope rotation programs.

1549 T Psychology. Structure of the Self-Sentiment. The research will need the calculation of large matrices of intercorrelations of measures hypothesized to involve the self-sentiment. Later stages will require centroid factor analysis programs, oblimax rotation, and oscilloscope plots. It may be necessary to calculate factor scores by the Hurley program.

1550 State Water Survey. Raindrop Analysis, R - Z Comparisons. A set of data will consist of all the rainfall rates R that are associated with a particular reflectivity Z and synoptic type. The mean R and variance of R will be calculated in normal manner. R_0, such that $\sum_i |R_i^2 - R_i R_0|$ is a minimum will be calculated. This calculation will be carried out by successive calculation of $\sum_i |R_i^2 - R_i R_0|$ and adjusting R_0 appropriately for minimum. The end results of R_0 determined by the above method will be related to the reflectivity values, Z, to determine an optimum estimate of rainfall rate from radar data.

1551 Educational Research. Factor Analysis of Pupils' Ratings of Teachers. The problem is to determine the factorial structure of pupils' ratings of approximately 100 sixth-grade teachers on 12 rating-scale items, and to see how this structure varies according to (a) whether the pupils were rating their actual or their ideal teacher, and (b) whether the pupils were rating before or after an experimental group of teachers had been given information about their pupils' ratings, and (c) whether the teachers rated were in the experimental group or the control group, which did not receive information concerning their pupils' ratings.

1552 Electrical Engineering. Calculation of Transient Response in An Ionized Medium. The problem is associated with the calculation of the transient response due to a magnetic current sheet in an ionized medium. This part of the calculation is needed for the numerical evaluation of the Laplace Transform involved.

1553 Dean's Office, College of Liberal Arts. James Scholars Research. This will be a continuing study in the selection and training of superior students, both at the undergraduate and at the graduate level of college. This research is a part of the James Scholars program of the College of Liberal Arts and Sciences.

Various analyses will be performed to try and correlate various data concerning the problem of what is a superior student and how he can best be selected and encouraged early in his college career. Among the methods to be used are correlations and factor analyses.

1554 T Civil Engineering - Structural Research. Analysis and Design of Single Span Highway Bridges Loaded by a Moving Vehicle. This problem is concerned with the development of a simplified method of analysis and design for a single span highway bridge subjected to moving loads. In the course of the investigation it is planned to accumulate and study both the analytical and available experimental data on the subject. In the first stage of this investigation it is desired to obtain an extensive number of additional solutions covering more fully the significant parameters by making use of the available program for the problem, that is, Illiac Program 1265.

1555 Civil Engineering - Structural Research. Analysis of Three Span Continuous Beams Subjected to a Moving Vehicle. A study of the dynamic response of three span continuous beams was initiated and resulted in the development of an Illiac Program, Problem Number 1234 T. In the present investigation it is desired to obtain additional solutions using the above program to study in detail the effects of the parameters involved.

In addition, the program will be modified to handle the case of a single span beam. In the course of this work it is also anticipated that solutions will be obtained with Illiac Program 1265 for purposes of comparison. The latter program is for the same general problem, but is based on a different theory.

1556 Digital Computer Laboratory. Error Correcting Codes Generated From Finite Fields. An error correcting code for single errors and adjacent double errors can be formed whenever one can find a finite field generated by some n^{th} degree polynomial $P(x)$ such that $x^k + x + 1$ 0 mod $P(x)$ for some integer k.

All coefficients are taken modulo 2. This routine will be written to find the minimum period m such that $x^m P_1(x) = P_1(x)$ modula $P_2(x)$ for any two arbitrary polynomials $P_1(x)$ and $P_2(x)$.

1557 T Civil Engineering. Response of a Nonlinear Multi-Degree of Freedom System to an Arbitrary Base Disturbance. The general nature of this research problem concerns the determination of response of a multi-degree of freedom, nonlinear, damped mechanical system to an arbitrary base disturbance. This problem is related to the effect of a ground shock or earthquake on a structure when the given structure is allowed to deform inelastically. The program will be used to integrate the following n second order, nonlinear, differential equations:

$$m_i \ddot{x}_i + c_i x_i' + q_i(x) = f_i(t)$$

x = displacement (response)

c = damping coefficient

$q(x)$ = nonlinear resistive force

$f(t)$ = time dependent forcing function .

1558 T Psychology. Distress-Relief Quotient Intercorrelations. The problem is the correlation of the Distress-Relief Quotient, applied to thematic Apperception test protocols, with counseling outcome measures (movement ratings, number of months in therapy, number of therapy sessions, and rating of emotional disturbance). The raw scores and various other functions of this tension-assessing scoring scheme will be correlated with these outcome measures to isolate the components contributing to the correlations and to explore any other methods of combining the distress, relief, and neutral ratings which make up the Distress-Relief Quotient. For another sample of subjects the Distress-Relief Quotient and components of this ratio will be correlated with related test variables across subjects (Minnesota Multiphasic Inventory Scores, Gilbert Self Interview Ratings, Ewing Personal Rating Form, and Rorschach Scoring Categories). The Pearson product moment correlation is the statistical model used. The Distress-Relief Quotient is a proposed method of assessing tension in written documents.

1559 Psychology. Factor Analysis of MMPI Scales. This is a study of the relationships of 60 personality tests (scales)(some of them standard and some new), each consisting of items in the Minnesota Multiphasic Personality Inventory. It is desired to compute the intercorrelations of the 60 scales, and also to factor analyze for (a) the 50 men subjects (b) the 50 women subjects, and (c) the whole group of 100 subjects. Results will show how many dimensions, and what kind, are included in the 60 tests. Method of factor analysis is centroid method with rotation to oblique simple structure.

1560 T Physics. Integration of Characteristic Annealing Functions. This program is designed to evaluate certain integrals for use in processing the results of an isothermal annealing experiment. Suppose that the value $P(t)$ of some property of a specimen is decreasing at constant temperature because of a distribution of thermally activated processes whose activation energies cover some range of values.

Then

$$P(t) = \int_0^\infty P_0(\epsilon) f(\epsilon)\, \Theta(\epsilon,t,T) d\epsilon,$$

where $P_0(\epsilon)$ is the density of the initial activation energy spectrum. When all processes having activation energies in the interval $d\epsilon$, centered on ϵ_0, have gone to completion, the net decrease in P due to the completion of these processes is $P_0(\epsilon_0)d\epsilon$, if $d\epsilon$ is small enough.

$f(\epsilon)$ is a monotonically increasing function of ϵ which expresses the degree of completion of the distribution of annealing processes due to all previous treatment. $f(\epsilon) = 0$ at $\epsilon = 0$, and 1 at $\epsilon = \infty$.

$\Theta(\epsilon,t,T)$ is the same sort of function as $f(\epsilon)$, and expresses the degree of completion of the process having activation energy ϵ when the anneal at temperature t has gone on for time t.

The experiment measures $P(t)$; from values of $P(t)$ we wish to obtain values for $P_0(\epsilon)$.

Now

$$P(t_1) - P(t_2) = \int_0^\infty P_0(\epsilon) f(\epsilon) [\Theta(\epsilon,t_1,T) - \Theta(\epsilon,t_2,T)]\, d\epsilon$$

and if $t_2 - t_1$ is not too large, we can say that

$$P(t_1) - P(t_2) = \overline{P}_0(\epsilon_0) \int_0^\infty f(\epsilon)[\Theta(\epsilon,t_1,T) - \Theta(\epsilon,t_2,T)]\, d\epsilon,$$

where $\overline{P}_0(\epsilon_0)$ is the average density of the spectrum in a neighborhood of ϵ_0, and ϵ_0 is the center of gravity of the integrated area.

$$\epsilon_0 = \frac{\int_0^\infty \epsilon f(\epsilon)[\Theta(\epsilon,t_1,T) - \Theta(\epsilon,t_2,T)]\, d\epsilon}{\int_0^\infty f(\epsilon)[\Theta(\epsilon,t_1,T) - \Theta(\epsilon,t_2,T)]\, d\epsilon} .$$

ILLIAC ENGINEERING CHANGES

Change In Illiac 8 Order

Circuitry has recently been installed in Illiac which enables the programmer to use the 8v n (input) orders as shift orders, enabling unbiased multiplication by the factors 2, 4, or 8 via shifting.

Trouble previously occured when the following sequence of orders was executed:

	91 4	stops on a 5th hole character
input order	8v n	$n \leq 3$
	91 4	

This sequence of orders resulted in the reading of the same 5th hole character twice. The new circuit eliminates this irregularity and allows the programmer to use these special shift orders at his convenience.

The following example illustrates the effects in A and Q when an 80 n ($n < 4$) is obeyed:

n = 3

Initial state of A Q

$$A \quad a_0 \quad a_1 \quad a_2 \quad a_3 \quad a_4 \quad \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \quad a_{36} \quad a_{37} \quad a_{38} \quad a_{39}$$

$$Q \quad q_0 \quad q_1 \quad q_2 \quad q_3 \quad q_4 \quad \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \quad q_{36} \quad q_{37} \quad q_{38} \quad q_{39}$$

State of A Q after obeying 80 3

$$A \quad a_3 \quad a_4 \quad a_5 \quad a_6 \quad a_7 \quad \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \quad a_{39} \quad 0 \quad 0 \quad 0$$

$$Q \quad q_0 \quad q_4 \quad q_5 \quad q_6 \quad q_7 \quad \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \quad q_{39} \quad 0 \quad 0 \quad 0$$

Illiac Tape Alarm

In the past it has been the custom for suppliers of Illiac tape to dye a substantial portion of the end of each role of tape a distinctive red

so that the operator can be conscious of the fact that the tape supply in the punch is becoming depleted. Lately it has been noted that this dyed portion has become shorter and shorter. Combined with the high speed of the punch this increases the probability that the tape can become exhausted and be pulled from the spool before the operator can notice it.

In order to automatically monitor the tape supply a lamp, photoelectric cell and associated bleeder resistors have been installed in the punches in such a way that as the tape gets low a signal is obtained from the photoelectric cell. This signal is used to gate a flipflop and an associated indicator neon located in the punch control chassis to a "1" state. This condition of this flipflop is used to inhibit the "A" gate from the punch from turning the TSP flipflop to a zero state. Illiac will hence hang-up at the beginning of any subsequent punch output order. A manual pushbutton mounted on the control panel is used to reset the out-of-tape flipflop after the tape has been replenished. A bypass switch is also provided on this circuitry which would be used in the event of failure. The sensitivity of the photoelectric cell combination can be varied in order to provide for variations in different photoelectric cells and in order to provide a means of controlling the amount of tape left in reserve when the cut-off point is reached.

To date two punches have been so modified. Modification of the remaining punches is underway.

Table I shows the distribution of Illiac machine time for the month of November.

TABLE I

	Hrs:Min	
Scheduled Maintenance	77:25	
Unscheduled Maintenance	12:20	
Drum Engineering	10:29	
R.A.R.	:10	
Leapfrog	3:15	
Wasted	:30	
Library Development	4:52	
Demonstrations	:33	
Classes	10:46	
		120:20

TABLE I (cont'd.)

Use by Departments

	Hrs:Min		
Agricultural Economics	2:27		
Agronomy	7:23		
Animal Science	1:09		
Astronomy (Nonr 1834(22))	1:19		
Bur. of Ed. Research (TR US PHM1839)	:37		
Bur. of Ed. Research	16:28		
Bur. of Ed. and Business Research	:08		
Education	:34		
Chemistry (NSF G-7336)	2:48		
Chemistry (Nonr 1834(13))	1:14		
Chemistry (AEC AT(11-1)-691)	32:19		
Chemistry	6:33		
Coordinated Science Laboratory	57:01		
Physics (Nonr 1834(12))	6:41		
Physics	43:40		
Digital Computer Laboratory (NSF G-9503)	5:28		
Digital Computer Laboratory (AEC AT(11-1)415)	:53		
Digital Computer Laboratory (Nonr 1834(27))	20:55		
Digital Computer Laboratory	:45		
Stanford Research Institute	2:54		
Electrical Engineering (NASA NSG 24-59)	3:42		
Electrical Engineering (AF 33(616)-6079)	1:10		
Electrical Engineering (NSF G7421)	:54		
Electrical Engineering	7:01		
Economics (NSF G-7056)	6:53		
Economics	:09		
Theo. and Applied Mechanics (ORD 593)	:24		
Theo. and Applied Mechanics (NOBS 72069)	:20		
Theo. and Applied Mechanics	2:09		
Psychology (1715)	13:47		
Psychology (NIH M-2331 Act 7289)	:10		
Psychology (Nonr 1834(11))	4:34		
Psychology (MD 2060)	:35		
Psychology (AF 49(638)-371)	:02		
Psychology	44:19		
State Water Survey (DA 36-039 SC 75055)	1:34		
State Water Survey	1:07		
Mechanical Engineering (DA 11-022 ORD-1980)	:03		
Mechanical Engineering	4:38		
Structural Research (AASHO Road Test)	2:50		
Structural Research	52:35		
Natural History Survey .	:20		
L.A.S. College	:23		
Institute of Communications Research	3:40		
Dairy Science	:07		
Aeronautical Engineering	:15		
Min. and Met. Engineering (TR US AF 6770)	:05		
Food Technology	4:09		
Geology	:30		
Veterinary Pathology and Hygiene	:05		
		369:46	
			490:06

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 10:30 a.m. Since the periods between 7 a.m. and 10:30 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance, and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for November.

TABLE III

Memory	1
Reader	4
Punch	1
Camera or Scope	10
Drum	8
Unknown	4
Total	28

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
11/2/59	20:35	:01	3:24	1	(1) Camera Failure	0	:22	0
11/3/59	20:25	:00	3:35	0		0	:00	0
11/4/59	19:43	:27	3:50	2	(1) Reader "B" error (2) Camera Failure	0	:20	0
11/5/59	18:52	:36	4:32	2	(1)(2) Camera Failure	0	:00	0
11/6/59	14:44	5:25	3:51	1	(1) Memory Control	0	:20	0
11/9/59	19:59	:01	4:00	1	(1) Camera Failure	0	:00	0
11/10/59	20:29	:01	3:30	1	(1) Camera Failure	0	:00	0
11/11/59	19:59	:01	4:00	1	(1) Camera Failure	0	:00	0
11/12/59	20:00	:00	4:00	0		0	:40	0
11/13/59	19:58	:02	4:00	2	(1) Unknown (2) Drum Failure	0	:06	0
11/16/59	20:17	:02	3:41	1	(1) Punch #3 Jammed	0	:00	0
11/17/59	20:28	:00	3:32	0		0	:00	0
11/18/59	20:48	:02	3:10	2	(1) Reader "B" error (2) Unknown	0	:34	0
11/19/59	19:58	:02	4:00	2	(1) Unknown (2) Camera Failure	0	:04	0
11/20/59	17:36	2:30	3:54	2	(1)(2) Drum Failure	0	:00	0
11/23/59	20:00	:00	4:00	0		0	:30	0
11/24/59	19:58	:55	3:07	2	(1) Reader "B" error (2) Drum Failure	0	:00	0
11/25/59	20:19	1:24	2:17	2	(1) Reader "B" error (2) Drum Failure	0	:00	0
11/27/59	19:57	:03	4:00	3	(1)(2)(3) Drum Failure	0	:43	0
11/30/59	19:02	1:03	3:55	3	(1) Unknown (2)(3) Camera Failure	0	:06	0
TOTALS	393:07	12:35	74:18	28		0	3:45	0

PART VI

IBM 650 USE AND OPERATION

New IBM 650 Codes

During the month of November two new routines were added to the IBM 650 Library.

K3'-57' Two-Digits Frequency Count. This routine counts the number of times each two-digit number, 00, 01,....99, appears in a particular field on a set of cards. There may be a maximum of 36 fields on a card, with the fields numbered 1, 2,....36 across the card, but there may be an unlimited number of cards in a set or case. The routine prints the "frequency count", and the "percentage distribution" of each two-digit number.

(L. Matsunaga)

C3'-58' Comparison Post Mortem. This program has two parts. Part 1 initially loads any program on the drum onto magnetic tape. At any later time (for example, after a failure) Part 2 can be used to compare the current state of the drum with the initial state which has been preserved on tape. Each changed drum location will be printed on a card giving location, original word, and altered word.

(M. E. Suhre, Jr.)

IBM 650 Usage

During the month of November specifications were presented for 7 new problems. This list does not indicate how the IBM 650 was used because large amounts of machine time may have been consumed by problems with numbers less than 56' T. Numbers followed by T are for theses.

56' T Agronomy. Variation In Different Corn Single Crosses. The variation of three different plant characteristics (ear height, ear weight, and

number of rows) is being studied within 72 different single crosses. Analysis of variance is used to determine the variation within the different single crosses for each plant characteristic.

57' Psychology. Multiple Discriminant Analysis of Objective Tests. This involves an application of C. R. Rao's procedure for multiple discriminant function analysis among more than two groups, thus the Illiac program (for the 2-group case) cannot be used.

A 650 program utilizing the University of Toronto "matrix package" routine for carrying out a series of matrix operations will be written.

The analysis involves the formation of the Product-Sum matrix within groups (W) and its inversion, the Product-Sum matrix between groups, the formation of the matrix solution for $W^{-1}B$, and the formation of 3 vectors of $W^{-1}m' - 1/2mW^{-1}m'1$ where m is a vector of means and 1 is a unit vector.

58' Civil Engineering. Class Problems for C.E. 297-497. It is planned to run three problems to acquaint the students with the fundamentals of programming.

Problem No. 1 is a short, self-contained program to read data, evaluate the design moments in a beam for successive positions of 2 concentrated loads, and punch the results.

Problem No. 2 is a closed subroutine to perform the design of a built-up beam through successive trials.

Problem No. 3 is a complete design program, using Problem No. 2 as a subroutine, involving a reasonable number of logical decisions based on specification requirements.

59' Digital Computer Laboratory. Sum Wakefield Series. The series representation for the energy and spontaneous magnetization of an Ising lattice will be evaluated for different values of the temperature. These results will be compared against similar results obtained by a Monte Carlo procedure.

60' Structural Research. Evaluation of Design Coefficients for Prestressed Concrete Members. This program provides the solution of design coefficients

for prestressed concrete members with several shape variables. The equations to be solved are simple in mathematical form but are tedious and subject to errors by slide-rule solution. A digital computer program, however, is ideal for this problem because of the repetitive operations.

61' Education. Teacher Placement Program. The purpose of this program is to provide a faster and more efficient method of selecting qualified candidates for positions in the field of education. Hence, this is primarily an administrative problem.

Presently, a great portion of the time used to select applicants for positions is given to the clerical processes of matching applicants' qualifications against job requirements. It is hoped that by using the IBM 650, this portion of selecting applicants against jobs will prove to be faster and more efficient. Also, it is hoped that this system will later provide information useful in compiling statistical reports and other such studies.

62' T Chemistry. Structure of $BaS_2O_3 \cdot H_2O$. The research problem is solving the crystal structure of $BaS_2O_3 \cdot H_2O$. The first step (this calculation) is to correct observed intensities (I) to structure factors (F). This is done by a calculation of absorption corrections, Lorentz-polarization corrections, velocity corrections and finally taking the square root of the corrected I values. In addition this program calculates a value for the scattering factor for each atom for each observed intensity, (an extrapolation procedure using tables fed into the machine). And lastly, the program calculates weighting factors for each reflection which can be used in a least squares refinement of the structure in the latter stages of the structure determination.

Table I' shows the distribution of the IBM 650 machine time for the month of November.

TABLE I'

	Hrs:Min	
Regular Maintenance	12:58	
Unscheduled Maintenance	14:48	
Library Development	8:57	
Log Summation	:46	
Air Conditioning	6:13	
Wasted	21:41	
		65:23

TABLE I'
(cont'd.)

Use by Departments

	Hrs:Min		
Mathematics 395	26:59		
Civil Engineering 297	2:12		
Agricultural Extension	4:39		
Agronomy	1:45		
Chemistry	:10		
Digital Computer Laboratory	1:27		
Physics	2:02		
Psychology	:53		
Statistical Service Unit	60:41		
Structural Research	8:54		
Theor. and App. Mechanics	:57		
		110:39	
			176:02

Error Frequency and Analysis

The IBM 650 is normally on from 8 a.m. to 5 p.m. The machine is used for preventive maintenance from 8 a.m. to 12 noon on Wednesdays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for November.

TABLE III'

533	5
Tape Unit	3
Floating Point	1
Fuse on 650	1
Storage Unit	7
Machine not warmed up enough	1
Total	18

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
11/2/59	3:38	2:07	:19	3:11	1		533 read hopper was tight
11/3/59	7:49		1:36	:52	2		(1) New brush put in 533 read (2) Bad Relay
11/4/59	2:56	3:35	:50	1:39	1		Multiple and blank bits
11/5/59	4:26		5:27	:07	1		533 gave extra answer cards
11/6/59	7:06		1:39	:15	2		(1) Relay replaced in tape unit (2) Fuse blew on 650
11/9/59	8:33		1:20	:32	0		Repair time for locating floating point trouble. Bad tube unit
11/10/59	9:06			:19	2		(1) Relay replaced in tape unit (2) 533 gave extra answers
11/11/59	4:49	3:57		:14	6		(1)-(6) Storage unit error light but no error. Reason unknown.
11/12/59	8:08			1:02	1		Manual operations produce storage selection light. Reason unknown.
11/13/59	6:35		1:52	:33	1		Double bits and no sign in distributor.
11/16/59	6:32		1:40	:48	0		Eng. time for checking 533
11/17/59	5:58			:11	0	2:51	
11/18/59	5:22	:10		:26	0	3:22	
11/19/59	8:50			:10	0		
11/20/59	8:25			:35	0		
11/23/59	4:12			4:48	0		
11/24/59	6:12		:05	2:53	1		Card jam in 533 read
11/25/59	5:28	3:09		:23	0		
11/30/59	6:17			2:43	0		
TOTALS	120:22	12:58	14:48	21:41	18	6:13	

PART VII

GENERAL LABORATORY INFORMATION

Seminars

"Some Recent Developments in the Numerical Summation of Series", by Dr. J. C. P. Miller, Visiting Professor, University Mathematical Laboratory, Cambridge, England, November 9, 1959.

"An Automatic Polynomial Approximation Routine", by Clinton R. Foulk, Digital Computer Laboratory, University of Illinois, Urbana, Illinois, November 16, 1959.

"Stepwise Numerical Integration of Ordinary Differential Equations by Taylor's Series", by Dr. J. C. P. Miller, Visiting Professor, University Mathematical Laboratory, Cambridge, England, November 23, 1959.

"Stepwise Numerical Integration of Ordinary Differential Equations by Taylor's Series" (Cont'd), by Dr. J. C. P. Miller, Visiting Professor, University Mathematical Laboratory, Cambridge, England, November 30, 1960.

Reports

"On the Dynamic Design of Non-Regenerative Transistor Circuits", by Toshiro Kunihiro, November 19, 1959. (Report No. 94)

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Physics

UNIVERSITY OF ILLINOIS

GRADUATE COLLEGE

DIGITAL COMPUTER LABORATORY

TECHNICAL PROGRESS REPORT

PART I - HIGH-SPEED COMPUTER PROGRAM

PART II - CIRCUIT RESEARCH PROGRAM

PART III - MATHEMATICAL METHODS

PART IV - ILLIAC USE AND OPERATION

PART V - IBM 650 USE AND OPERATION

PART VI - GENERAL LABORATORY INFORMATION

December, 1959

PART I

HIGH-SPEED COMPUTER PROGRAM

This work is supported in part by Contract No. AT(11-1)-415 of the Atomic Energy Commission and in part by the University of Illinois. Contract No. AT(11-1)-415 is supported jointly by the Atomic Energy Commission and the Office of Naval Research.

A. Logical Design

1. Exponent Arithmetic Unit Adder

Two designs for the logic of a speed-independent adder were completed. One of these utilizes diode matrix logic, the other one uses AND-OR complexes. A comparison of complexity of the two designs will be made.

(A. A. Avizienis)

2. Main Arithmetic Unit Division Predictor

The problem as to how thorough a check for zeros must be made after a set of circuits has been "cleared" to zero is being studied. A three halves circuit is being designed using transistor and matrix logic and also with matrix logic alone. It is hoped that by studying these designs answers may be found to the following question: Is it sufficient to check for zeros at the inputs to AND circuits by feeding these same inputs to an OR circuit and examining its output, or must the emitter follower of the AND circuits also be checked?

(J. O. Penhollow)

3. Main Arithmetic Unit End Connections

The design of special selector end connections at the high end of the double length accumulator is based on a division of all the micro-operations comprising the order set into three classes. If $B = b_{-1}\ b_0\ b_1\ b_2$ --- designates the output of the M register selector for the A adder, and $A = a_{-1}\ a_0\ a_0^* \cdot a_1\ a_2\ a_2^*$ --- designates accumulator contents, the three classes of operation are discernible as follows:

a) A and B are signed numbers; a_{-1} is the apparent sign of A, b_{-1} is the sign of B, in the usual sense of two's complement;

b) (a_{-1} a_0) is considered adjacent to (q_{45} q_{46}), and does not hold sign information

c) Either a_{-1} or b_{-1} has the weight of +2 instead of -2, but (b) is not true.

A detailed analysis and description of the provisions for these operations is in a separate report. However the significance of the above classification may be gleaned from the fact that, prior to any gating operation affecting the contents of AQ or SR, control memory elements are set to prepare the data flow in accordance with one of the above interpretations of the register contents.

(R. R. Shively)

4. Control Design

The design of the subcontrol mentioned in the November report was continued and a workable design was achieved. Unfortunately though, this method of approach resulted in what appears to be a very expensive system since it requires 9 "C" elements, 11 OR, 6 AND, and 2 NOT circuits. Componentwise this represents 115 transistors and 280 diodes plus the needed driver circuitry. Therefore in an effort to determine if this is as expensive as it seems or if it is really typical, design was begun on a subcontrol to accomplish the same gating operations through use of Eccles-Jordan flipflops as memory elements.

(R. E. Swartwout)

B. Core Storage Unit

1. General Status

A considerable portion of the memory cycle time (about 0.5μs) has been the time required for the digit (rewrite) line noise to settle below the level of a sense signal following rewrite driver operation. This settling time has been reduced to about 0.2μs by decreasing the digit line current from 250 to 200ma and increasing the digit line

termination resistances to a value nearer the mean characteristic impedance of the lines. The reduction of digit line current causes a reduction in sense signal amplitude which, however, is easily compensated without loss of reliability since the sense signals are bipolar. With the above changes, a memory cycle time of 1.5μs or less appears to be very probable.

(S. R. Ray)

2. Address Decoder

An "address decoder" test circuit was constructed and some preliminary tests were made.

(B. E. Briley)

3. A Driver Circuit

With the advent of the availability of a PNP transistor which matches the NPN, 2N697, resonably well, the driver reported in the June 1959 Progress Report was modified in an attempt to achieve slightly better rise and fall times. One of the PNP transistors, a 2N1132, was added to the circuit to work with a 2N697 mate as a push-pull predriver. After the initiating signal has moved 10% of its full excursion the driver takes 175mμs to turn on and 225mμs to turn off a current of 1.6a. with a regulation of +14% and -18%. The driver is on or off if it moves to 90% of its full excursion. Total load voltage swing is 25v. The circuit is shown in Figure 1.

(J. L. Muerle)

C. Input-Output and Auxiliary Storage

Single-channel dropout data was taken on the Ampex FR300 Magnetic Tape Unit, at 150 inches/sec. and a packing density of 600 bits/inch. The reel of C-1 tape which was used had been damaged somewhat by previous occurrences of "pack slip". For this damaged tape, there was approximately 700 groups of bits lost, with an average of 4 bits per group, or a total of 2800 bits lost for the whole reel. It is expected that the dropout rate for undamaged tape will be considerably less.

(C. N. Liu)

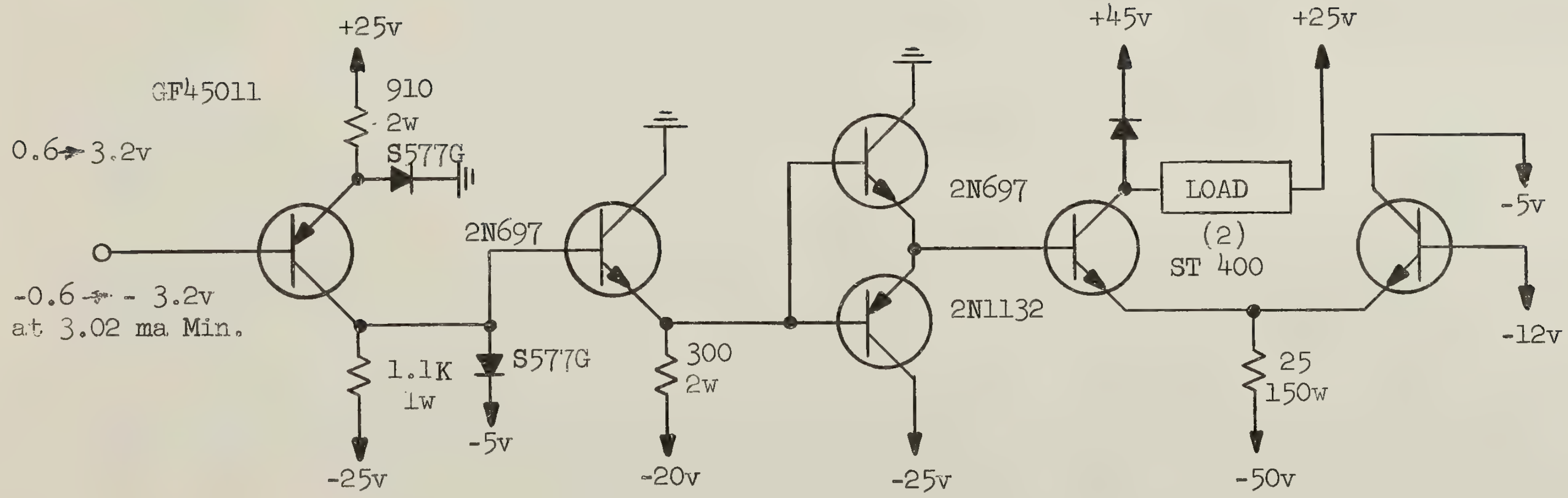


Figure 1
High Power Memory Driver

The equipment to detect one, two, and three-or-more transverse dropouts from the magnetic tape unit is being built in two chassis. The first chassis detects a single dropout in any one of the four channels, and performs some logical operations needed by the second chassis. The second chassis detects two and three-or-more dropouts. The first chassis has been built and is now working. The circuits have been designed so that if it becomes desirable to detect one, two, and three-or-more transverse dropouts in eight channels instead of four, it can be done by duplicating some of the four channel equipment.

(T. C. Piper)

Re-design of the remote control test unit and the J-element was begun this month. When completed this equipment will allow unattended programmed operation of the FR300 tape transport for testing purposes.

Data was taken of V_{eb} vs I_e (forward and reverse) for the 2N651. A table of this data will be incorporated into the Sir Kittsolver analysis routine.

(L. J. Peek, Jr.)

D. General Organization

1. Order Code

A number of changes in the order code were made as a result of trial programming. Double precision add (add to the floating accumulator the numbers in two consecutive memory locations) was eliminated. The number of shift instructions was reduced to 4: double-length left and right shifts (arithmetic), and single length logical shifts of the A-register. Furthermore, the shift instructions will not affect the exponent of the accumulator. The unnormalized add instruction performs a floating point addition of a single precision number from the memory to the floating accumulator, and corrects overflow, if necessary, by a right shift of one base 4 digital position. Normalized add first normalizes the accumulator and then performs an unnormalized add. Two instructions are provided to store the integer part of the floating accumulator, either as an address in a modifier register or as an unnormalized number in a register. After either instruction the accumulator will contain the positive fractional

part. Several instructions have been deleted and two new ones added: add to Q (without regard for exponent), and store Q (giving it the exponent of A). Both divide and integer divide leave the quotient in the accumulator and place the remainder in a fixed flow-gating register.

(J. A. Resh, R. H. Flenner, D. B. Gillies)

2. Advanced Control

As a preliminary to drawing a state diagram, charts were drawn up for the various types of instructions showing the various interlocks required, and the time-ordering of events necessary during execution by advanced control. Although this is not complete, it is important because of the notation introduced and the fact that a number of sequences have now been combined.

(J. A. Resh)

PART II

CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

1. Summary of the December Work

As last month the work was concentrated in these areas:

(a) Flow-gating (H. Guckel)

(b) Transistor Transients (T. Kunihiro)

(c) High Power Drivers (J. W. Baur)

A preliminary study was started on the oscillation of emitter-followers and the use of transistor-tunnel-diode combinations. This report will only deal with the first three subjects, deferring the account of emitter-followers and tunnel-diode work to the next report.

2. Flow-Gating

Considerable time was spent re-examining the theoretical background of flow-gating action. It was found in particular that certain restrictions (like feedback in the gate-in condition) could be eliminated, while a certain number of supplementary conditions (like equalization of the time constants of the networks feeding the transistor bases) had to be introduced.

Work was begun to design a driver for 13 flow-gating flipflops using the Fairchild 2N1420 transistor. This is an NPN Si-diffused mesa unit giving 2w at 25°C. At 150ma the dc pulse current gain is better than 100 while the collector capacitance is $< 35\mu\mu f$. The alpha-cutoff frequency is of the order of 100 mc. The design uses a Zener-diode input step-up into the base of a GF45011 transistor, the collector of which drives the 2N1420 base directly. The output is taken on the collector side. Rise and fall times are of the order of 40mμs.

The driver is shown in Figure 2.

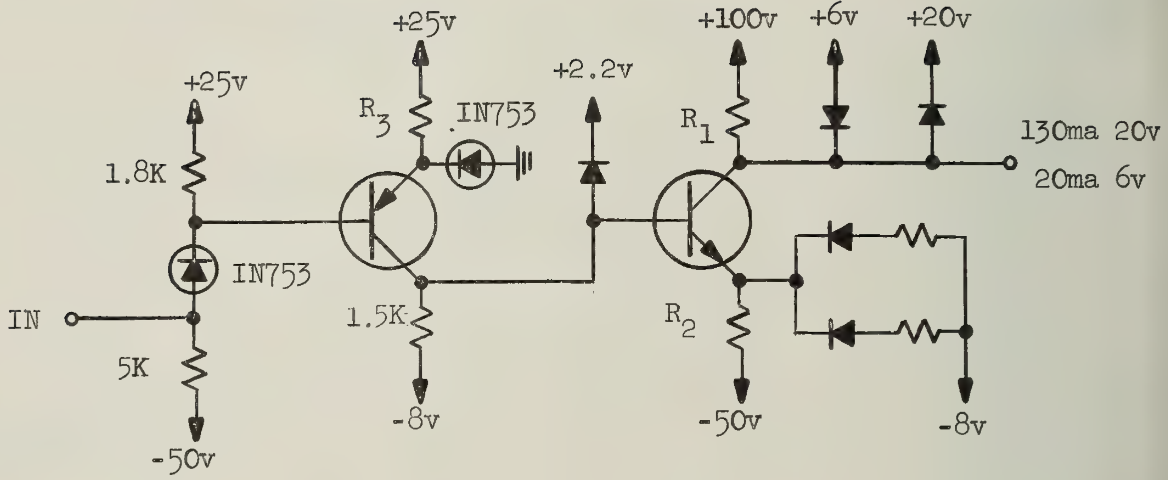


FIGURE 2

Driver for 13 Flow-Gating Flipflops (2 Base-Inputs per Flipflop)

R_1 R_2 R_3 Depend on the Exact Application.

3. Transistor Transients

A theoretical investigation was started in which the following points were considered:

Firstly, the transfer function of a non-regenerative, base-driven transistor circuit is derived by applying the linear equivalent circuit method. The results were experimentally verified. Secondly, the idea of the inverse-gain-bandwidth was introduced as the criterion of the dynamic design. Thirdly, the stability factor was examined. Finally, it was shown that a system constructed by various types of transistor switching circuits is reduced to a long train of unit chains formed by delay units and wave-shapers, and the maximum allowable number of delay units in a chain was discussed. The results obtained seem consistent with the design procedures for transistor switching

circuits established in the Digital Computer Laboratory, i.e., the emitter-follower logical circuits associated with restorers and flipflops. More details will be given in next month's report.

An interesting side-effect of these studies was an examination of the equivalent circuits used to represent transistors operated in the active non-saturating mode. A method was found to correct for slight non-linearities of the elements. Figure 3 shows an equivalent circuit found entirely satisfactory for all practical purposes when the expansions for Z_e, Z_c and Z_b given below are assumed.

$$Z_e = \frac{r_e}{1 + s r_e C_{se}}$$

$$Z_c = \frac{r_c}{1 + s r_c C_c}$$

$$Z_b = r'_b$$

$$\alpha = \operatorname{sech} \frac{W}{D_m \tau_m} (1 + s\tau_m)$$

$$\cong \frac{\alpha_0}{1 + s\tau_\alpha}$$

where

r_e = emitter resistance

r_c = collector resistance

r'_b = base spreading ohmic resistance

C_{se} = emitter diffusion capacity $\cong \dfrac{1}{1.5\, r_e\, w_\omega}$

C_c = collector depletion layer capacity

ω_α = $1/\tau_\alpha$ = normal alpha cutoff frequency

W = base width

D_m = diffusion constant for minority carriers

τ_m = average lifetime of minority carriers

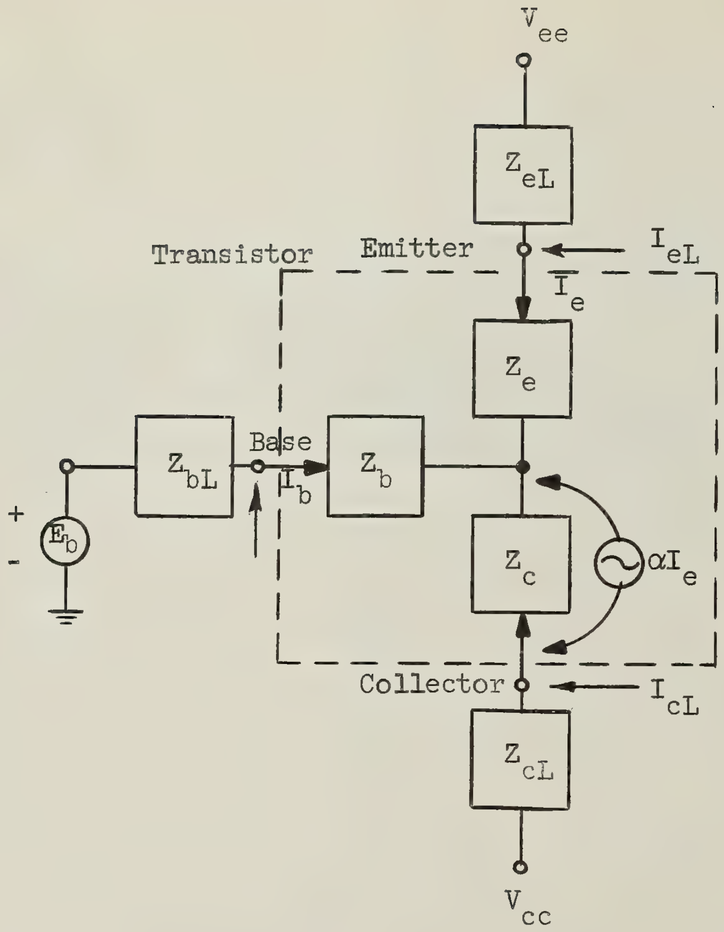


FIGURE 3

Equivalent Circuit for Transient Studies

4. <u>High Power Drivers</u>

A 250-base driver according to Figure 4 was completed and tested.

The 250-base driver utilizes 40 collectors in a parallel arrangement to achieve a current output range of 0 ma. to 550 ma. with a corresponding output voltage swing of -1 volt to + 1 volt. The output current is dependent upon the loading conditions prevailing, with the upper value of current determined by the variance of the -1 volt base value which deviates greatly for higher currents.

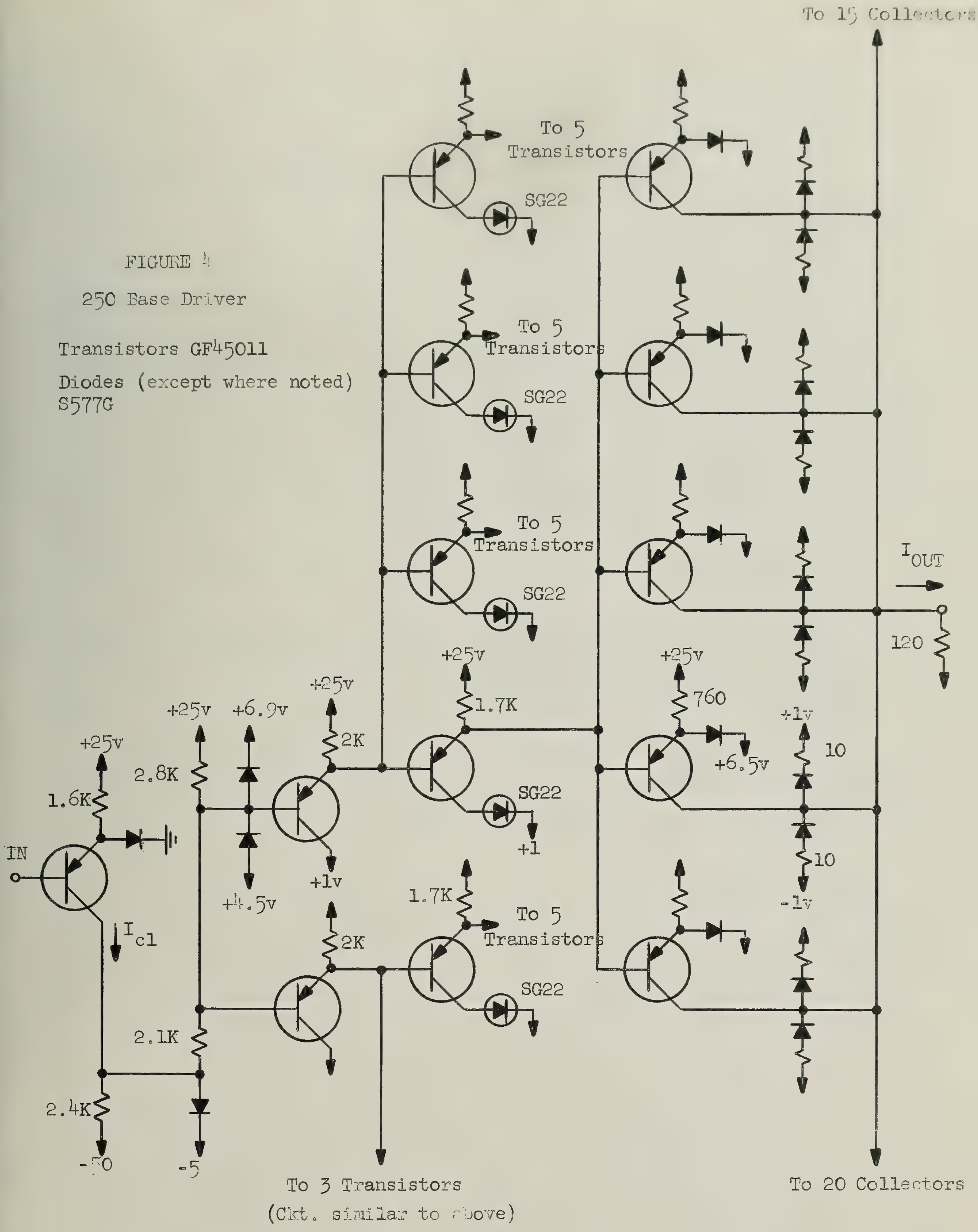
The input to the 250-base driver is a switching circuit requiring + 0.6 volts and a maximum DC input current of 1.2ma. The operation time of the driver (i.e., the time between the moment the input signal crosses zero and the moment the output signal crosses zero) is measured experimentally to be 18 mμsec., independent of the loading conditions. The rise time is

FIGURE 4

250 Base Driver

Transistors GF45011

Diodes (except where noted) S577G



characteristically a function of the load. A resistance load producing an output current of approximately 330 ma has a rise time of 20 musec; a parallel capacitor of 560 μμf increases this rise time to 22 mμsec.

The output variances as observed experimentally are tabulated as follows:

Current Output	Voltage Variation
260 ma	-1.35v to + 1.55v (no capacitance placed on load)
260 ma	-1.35v + .2v to + 1.55 + .3v (with 1000 μf, ripple variance)*
333 ma	-1.3v to + 1.35v (no capacitance placed on load)
333 ma	-1.3v + .1v to + 1.35 + .15v (560 μμf)*
333 ma	-1.3v + .3v to + 1.35 + .4v (1000 μf)*
450 ma	-1.1v to + 1.3v (no capacitance placed on load)
450 ma	-1.1v + .3v to + 1.3v (1000 μf)*
550 ma	-8v to + 1.2v (no capacitance placed on load)
	-8v + .2v to 1.2v + .1v (1000 μf)*

* The ripple observed is a damped sinusoidal variance. The ripple and rise time variance can be neglected for values of capacitance up to 200 μμf placed in the load.

It seems feasible to use high current transistors with fast switching capabilities in place of the present GF45011 transistors, and thus effect a decrease in cost. This possibility is being investigated.

PART III

MATHEMATICAL METHODS

1. Reduction of Roundoff Error in Floating Point Quadrature (Supported in part by the Office of Naval Research under Contract Nonr 1834(27).)

Experiments with the floating point quadrature scheme described in the November Technical Progress Report have continued. The reason for the large discrepancy in the results of Method I and Method II (following the notation of the November 1959 Technical Progress Report) was found to be largely due to an error in the code using Method I. This error was corrected and new tests were performed. It was found in these cases that only very small or virtually insignificant differences appeared between the results of the two methods. The reason for the relatively high accuracy of Method I is not understood. The results of some of the tests are shown below.

Test I:

Evaluate

$$I = \int_0^1 \frac{1}{3}\, dx$$

for N(= number of integration steps) = 50, 100, 200, 500, 1,000. Both Method I and Method II gave 0.33333333 as a result for all values of N. The roundoff error is expected to increase with N, but there is no evidence of it here.

Test II:

Evaluate

$$I = \int_0^1 mx\, dx$$

for m = 10, 1000 and N = 300, 900. In all cases Method II produced an exactly correct result while the maximum error produced by Method I was 4 in the least significant digit of the fractional part of the floating point number. In Method I the roundoff error always showed an increase, though small, with an increase in N.

Test III:

Evaluate

$$I = \int_0^1 (x - \tfrac{1}{3})(x - \tfrac{2}{3})\, dx$$

N	Method I	Method II
300	0.055555537	0.055555553
900	0.055555552	0.055555550

The exact answer is the repeating decimal fraction $0.0555^{\cdot}$. In Method I the roundoff error for the larger N is less than for the smaller N. This result is odd and the computation will be repeated in order to verify it.

(L. D. Fosdick)

2. Einstein Field Equations (Supported in part by the National Science Foundation under Grant G9503.)

Work continued on the numerical calculations. Results were obtained for some relativistic cases. These results showed, as reported in December 1958, that there is a maximum mass for equilibrium and that for some values of the total mass two configurations are possible, with different radii.

(J. Blankfield)

PART IV

ILLIAC USE AND OPERATION

New Illiac Codes

During the month of December six new routines were added to the Illiac Library.

KSL 4.50 - 272 Limited Information Estimation, Single Equation (LISE). This routine estimates parameters in economic models by the limited information single equation method. In the equation:

$$y_1 = B_{12}y_2 + B_{13}y_3 + \ldots + C_{11}z_1 + C_{12}z_2 + \ldots + U_1$$

the routine estimates the B's and C's and also calculates their standard errors. A parameter tape specifies which of the endogenous (y_i) and exogenous (z_i) variables are to be included in the equation under study.

(K. W. Dickman)

KSL 1.53 - 273 Extraction of the element with largest absolute value from each row of a matrix for use as communalities estimates.

(K. W. Dickman)

A1-M - 274 Standard Entry Floating Point Arithmetic (DOI or SADOI). This routine originated in the MISTIC Laboratory (Michigan State University) and is similar to but not identical to routine A1-63 of the Illiac Library. It is being incorporated in the Illiac Library so that several other MISTIC routines which use it can also be incorporated.

EA2-M - 277 — Integration in Floating Point (A1-M) by Quadrature Formula Q_{66} (a 6th degree polynomial approximation). (DOI or SADOI). This routine originated in the MISTIC Laboratory (Michigan State University) and must be used with A1-M-274. It uses a seven term integration formula to integrate a function specified by a closed subroutine with an error proportional to the ninth power of the interval size.

S10-S - 280 — Fast Low Accuracy Logarithm Routine (DOI or SADOI). This routine originated in the SILLIAC Laboratory (University of Sydney, Australia). This routine will compute 1/32 of the natural logarithm of an argument, accurate to approximately 1×10^{-6}. The duration of the routine is approximately 5 msec. Its use is recommended when the full accuracy (about 5×10^{-12}) of Routine S5-231 is not needed. This latter routine requires from 10 to 15 msec. to achieve the greater accuracy.

S11-S - 281 — Fast Exponential Routine (DOI or SADOI). This routine originated in the SILLIAC Laboratory (University of Sydney, Australia). Compared to Routine S4-212, this routine is only slightly longer (28 vs. 21 words), slightly more inaccurate (25×10^{-12} vs. 5×10^{-12}), but twice as fast (5.5 msec. vs. 11.3 msec.).

Illiac Usage

During the month of December specifications were presented for 23 new problems. This list does not indicate how the Illiac was used because large amounts of machine time may have been consumed by problems with numbers less than 1561 T. Numbers followed by T are for theses.

1561 T Mechanical Engineering. Heat Transfer from Enclosed Rotating Disc. The Illiac will be used to solve a difference equation approximation to a partial differential equation for the steady-state heat flow in a cylindrically symmetric rotating medium, subject to various boundary conditions. The distribution of temperature values will be computed at 10 axial values, and these will be repeated for 100 radial values, at each of which the solution at a given point will depend only on the present and previous radial solutions.

The program will also provide for:

1) Iterative solutions with various convergence criteria.
2) Variable parameters.
3) Solutions retaining old radial values both above and below the value at which the solution is being obtained, as well as only below.
4) Variable output format.

The equation to be solved is:

$$-A(RW' + BU')\frac{\partial \theta}{\partial R} + AW\frac{\partial \theta}{\partial \zeta} = 4\frac{\partial}{\partial R}\left(R\frac{\partial \theta}{\partial R}\right) + \frac{\partial^2 \theta}{\partial \zeta^2}$$

where A and B are parameters,

ζ is the axial variable,

R is the radial variable,

θ is the temperature,

W and U are power series in ζ,

$$W = -\frac{\zeta^2}{20} + \frac{7}{60}\zeta^3 - \frac{1}{12}\zeta^4 + \frac{1}{60}\zeta^5 + \ldots$$

$$U = 3\zeta^2 - 2\zeta^3,$$

and primes denote differentiation with respect to ζ.

1562 Agricultural Economics. Transportation Cost Functions. The general problem is concerned with a spatial price equilibrium model of the livestock-feed economy. Since the structure of transport rates for the products is basic to the spatial solution, it is necessary to obtain estimates of the costs between the points that represent each pair of regions. A model to reflect transport costs between market and supply source points was postulated as:

$$C_{ij} = a + b_1 M_{ij} + b_2 \sqrt{M_{ij}} + \epsilon .$$

Where C_{ij} represents the costs of shipping a product from point i to point j, M_{ij} is the rail mileage between i and j and a, b_1 and b_2 are the parameters to be estimated. A sample of data has been secured to represent the observable variable and the least squares procedure will be used to estimate the unknown parameters.

1563 T Mechanical Engineering. Simulated Sampling. In industrial work measurement the determination of an acceptable time value to be assigned to an activity is often based on an average task or cycle time obtained by timing several cycles of the activity with a stop watch. The key to accuracy in determining this average cycle time is the number of observations made of the activity. Thus, the basic problem is to determine what is the required number of observations or samples, N', necessary to make a selected statistical inference of the true average time, $\bar{X}'$, required for completion of the task.

There are available a number of different formulae that may be used to calculate values of N' from preliminary sample statistics. The writer desires to test the reliability and relative superiority of eight of these formulae by a process of simulated sampling on the Illiac.

A set of 5,000 scaled random normal deviates stored on the magnetic drum is to be used to represent a typical population of cycle times necessary to perform some industrial task. A preliminary random sample of 16 values is to be drawn from the drum and various statistics from such a sample are to be used to calculate the number of samples, N', required to make a selected statistical inference of the true population mean. N' random samples will then be drawn from the drum and used to calculate $\bar{\bar{X}}$, the estimate of the population mean value. The values of N' and $\bar{X}$ will then be punched out. This procedure will be repeated 999 times so as to obtain a truly representative picture of the distribution of N' and $\bar{X}$ for all of the eight formulae being tested.

1564 T Agricultural Economics. Linear Programming Model. Research problem is production possibility on Indian farms with given input constraints. The problem will involve calculation of multiple correlation, regression analysis and simplex method.

1565 Veterinary Physiology and Pharmacology. Magnesium Requirement of Pigs. Pigs were fed five dietary concentrations of magnesium. The adequate dietary level is to be determined by comparing the serum magnesium, weight gain, and efficiency of food utilization. The differences in these criteria between the groups and between experiments taking into consideration sex, litter, and initial weight gain are being compared statistically by means of the method of least squares.

1566 T Sociology. Factor Analysis of Returned Violators Data. Information regarding 25 interval scale variables such as age, months served, I.Q., schooling, etc., have been obtained from 250 inmates who have been returned to prison after a parole or some other violation. In order to study the relationship between these variables in returned violators, a factor analysis is proposed.

1567 State of New Jersey, Edward R. Johnstone Training and Research Center. Speech Defects of Mentally Retarded Children. As part of a larger study of simple language skills in retardates, errors in speech production are being analyzed to determine to what extent they are related to the articulation dimensions of speech. Our research has already revealed that substitutions of one phoneme for another in errors of speech production are distributed in the same way as Miller and Nicely found that perceptual confusions of speech are distributed when speech is presented to listeners at unfavorable signal to noise ratios. There are few confusions in either perception or production between voiced and unvoiced sounds. Although different classes of sounds that are alike on the voicing dimension are occasionally confused, most errors occur among sounds that are produced in the same manner but at different places in the mouth.

Illiac is requested for a new attack on this general problem...Illiac would be used to calculate phi coefficients and to obtain factors. Then it can be determined whether these factors correspond, in some fairly simple way, with the articulation dimensions of speech. Data have been obtained from 211 subjects on 24 variables. The variables will be correlated, factored, and then the factors will be rotated to simple structure.

1568 Chemistry. Radiation Kinetics. Under Illiac Problem Number 1031 there was developed a program to solve sets of parabolic partial differential equations which arise in the study of the kinetics involved in the radiation

chemistry of aqueous solutions. This program has been applied successfully to a number of simple cases, including an investigation of the validity of certain simplifying assumptions which chemists in this field had used in interpreting their data. It is now proposed to use the same Illiac program (possibly with slight modification) to investigate the consequences of more complicated kinetic mechanisms in an attempt to explain certain interesting experimental data.

1569 Institute of Communications Research. Language of Personality. Two sets of 40 adjectives were randomly selected from a set of 1,050 adjectives commonly used in describing persons. Opposites for each adjective were determined in order to construct scales with each end defined on which subjects might rate themselves and others. In this preliminary investigation all possible pairs of scales for each set of 40 adjectives were rated against each other in the following manner:

A Person Who Is:	Is Likely to be:
Rare (not usual)	Pliable __: __: __: __: __: inflexible

Since there are 780 possible pairs, each subject received only one-half of the pairs. Two different orders of presentation were used, yielding 8 groups of subjects. Correlations between scales are to be determined for each group and for certain combinations of groups. These measures of association are to be factored and the factors rotated to simple structure.

1570 Physics. Homogeneous Neutron Resonance Escape. This routine is a generalization of "Resonance Escape in U-H Mixtures" to include arbitrary binary fuel-moderator mixtures. It uses Monte Carlo method to calculate the probability that a neutron will slow down between two energies without being absorbed. It also stores averaged values of the flux and collision density in specified energy intervals. The fluxes, together with output from "Monte Carlo Doppler Broadening", will be used in an alternate method of calculating the escape probability.

1571 Physics. Monte Carlo Doppler Broadening. This routine uses routines from "Resonance Escape in U-H Mixtures" to calculate doppler broadened neutron resonance cross sections for a "general" resonance absorbing element

(no fission yet). After the program is read in, a data tape is inserted which specifies the number of neutrons per energy value for the Monte Carlo calculation, followed by a table of energy values. Output consists of groups of decimal fractions with signs, and gives the energy, the broadened absorption cross section, the broadened total cross section, and an "N" termination. This will serve as input for a subsequent integrating routine.

1572 T Agricultural Economics. Capital Accumulation on Southern Illinois Farms. This is a study of the pattern of capital accumulation, i.e. change in net worth, on 74 southern Illinois farms during the period 1956-1958. An attempt is being made to find the factors that may explain the variations in the rate of change of net worth on different farms. This involves a determination of the best combinations of factors that may explain the variations in farm and family earnings, which in turn explains the variations in the changes in net worth.

1573 T Psychology. The Interrelationships of Music Preference, Motivation and Personality Measures. The minimal requirements for the present research will include the computation of an 80 variable correlation matrix on 150 subjects (K-8). A full scale factor analysis will then be performed on the correlations (1.21). The extracted factors will then be rotated on an oblimax rotation (1.90) and the final rotation processes will be handled with 1.96. Various subroutines will involve obtaining change scores between two different testing sessions, etc. After an adequate rotational solution has been achieved the subjects' factor scores will be computed and second-order factors will be obtained and rotated, i.e. the same process will now be repeated on a smaller number of variables.

1574 Chemistry. Analysis of H_2+H Collisions. This program will analyze the results of a previous program which solved the equations of motion for three atoms under a given potential energy function. For an H_2 + H collision, the program will correlate initial conditions with respect to: 1) reaction or no reaction, 2) interchange of translational impact energy with vibration energy and rotation energy, and 3) interchange of vibration energy and rotation energy upon impact.

This correlation will be made indirectly. It is suspected that crit-

ical factors will be found among the following quantities, which characterize a given collision (being calculated from the initial conditions under constant potential energy).

At each of the following times:

(1) t_o: time of closest approach,

(2) $t_{pl,2}$: $\pm$ 1/4 of a vibrational period from the time the line of centers is in the plane of diatomic rotation,

(3) $t_{fl,2}$: $\pm$ 1/4 of a vibrational period from the time which is the middle of the high force application time,

a calculation of:

(1) the vibrational phase angle,

(2) the rotational phase angle,

(3) orientation of the line of centers with respect to the rotation plane of the diatomic,

(4) length of line of centers,

will be made.

One object of the original program is to obtain the probability of reaction per collision as a function of impact energy. However, only 1% of the 700 collisions so far studied has resulted in reaction. From an analysis of these collisions it should be possible to set up criteria which will exclude certain large regions of "initial condition space" as being very unlikely to lead to reaction. This will enable better utilization of computer time in the original collision program.

The present program will give an impact parameter, which is needed to turn the results of the previous program into a reaction rate constant. The present program will also calculate initial and final translation, vibration, and rotation energies for each collision. These will be correlated with reaction or no-reaction, and the systematics of the dependance of the various energy interchanges upon the magnitudes of the interchanges and the initial values of the energies will be investigated.

1575 Civil Engineering. Structural Analysis of Parallelogram Plate. The structural analysis of a orthotropic parallelogram plate and of a skew-anisotropic parallelogram plate is to be undertaken. For this structural analysis, the influence coefficients of deflection and bending moment must be obtained. For this purpose, the inverse matrix of the given stiffness matrix must be solved.

1576 T Agronomy. Nitrogen Reaction in Soils. This problem is a continuation of field experiments to compare Winter, Spring, and Sidedress applications of ammonium and nitrate forms of nitrogen fertilizer using 40 and 80 lbs. of nitrogen per acre plus a check plot with no nitrogen. This year's study consists of 3 experiments in central Illinois. Each experiment has a 3 x 2 x 2 factorial treatment arrangement plus a check with 4 replications. The experimental design used was a randomized complete block and analysis of variance will be used to analyze the data.

1577 Petroleum Engineering. Calculation of Physical Parameters of Geological Beds from Resistivity Data. Illiac will be used to compute the physical parameters of geological beds from the resistivity data recorded on well logs. The process will involve substitution of the corrected data obtained from well logs into semi-emperical formulas to calculate the porosity ϕ, the fluid saturation Sw, the resistivity of the fluids within the pores Rw and bed thickness e. The simple emperical formulas are given below.

1) $Rw = (Rmf)_{corrected} \; e^{-2.34\, SP/Kt}$

$Kt = 0.21\, T$

SP = Spontaneous potential measured from well logs

Rmf = Resistivity of mud filtrate (available).

2) $\phi = \frac{1}{F^n} = \frac{1}{\left(\frac{Ro}{Rw}\right)^n} = \left(\frac{Rw}{Ro}\right)^n$

Ro = a value to be obtained from the well logs.

3) $Sw = \left(\frac{Ro}{Rt}\right)^{1/m} = \frac{R_i \times Rw}{Rt \times Rmf} = \left(\frac{Ri}{Rt} \times \frac{Rw}{Rmf}\right)^{1/m}$

Ri = Resistivity of the invaded formation to be obtained from the well log

Rt = True resistivity of the virgin formation.

4) e is normally obtained from SP or γ ray log.

To correct the resistivity data, it will be necessary to solve Laplace's equation, using the appropriate boundary conditions. Another approach, which might be attempted in the future, is the use of the sum of the potentials due to images produced by 3 dimensional boundaries.

1578 Structural Research. Equation Involving Bi-harmonic Operator. The purpose of this problem is the development of programs for the solution of equations involving the bi-harmonic operator, more specifically, the equation of the flexure of thin plates by finite differences. The method of relaxation with a weighting coefficient will be used to solve the finite difference analog of the differential equation.

Optimum weighting coefficients will also be determined for the boundary conditions of simply and multiply connected regions most frequently encountered in the field of Structural Engineering.

1579 Food Technology. Objective Description of Freeze Dehydrated Beef. Subjective tests for evaluating the quality of freeze dehydrated meat are needed so that purchase specifications may be written and enforced. These tests must match organoleptic or eating quality tests to be of value. A variety of samples have been prepared and have been subjected to physical and chemical tests as well as taste panel tests. What correlation exists between the two sets of data must be determined.

The mathematical method used is the method of least squares.

1580 Aviation Psychology Laboratory. Summation Program. This program is supplementary to problems #1104 and #1141. It will take the output of these two problems and obtain summations and/or means across subjects.

#1104 generates a large number of time-on-target scores for each subject and #1141 generates a frequency distribution of error scores for each subject. The summation program answers the need for a rapid reduction of all these scores to group means.

1581 Digital Computer Laboratory. Equilibrium in Ionized Air. The equilibrium percentages of the various ionized components arising in highly heated air will be computed.

1582 Education, Purdue University. How Test Revision. For a number of years a test known as the How Test has been used by the Division of Educational Reference at Purdue University to measure employee needs and goals and also training techniques for various occupations. This test which contains over 136 items

is in need of revision. It is too long. Although the test has given excellent results in discriminating among various types of persons, the users of the test have never understood clearly why the test works as well as it does, for the factorial composition of the test is unknown. If the test becomes better understood, it will be possible perhaps to shorten it, to standardize it, and finally to publish it for others to use.

The purpose of this test analysis is to attempt to understand the primary factors which are measured by the test. It is proposed first to calculate phi coefficients for the entire set of test items for a sample of 500 persons. Next a factor analysis will be done. Finally the factors will be rotated to both orthogonal and oblique simple structure.

1583 Civil Engineering. Statistical Analysis of Variables Affecting the Stability of Soil-Aggregate Roads. It is desired to compute standard deviations, regression weights and coefficients of multiple correlation to test the significance of the relation between these variables for surface and subgrade courses of soil-aggregate roads.

The number of observation in this study is thirty and the variables involved are twelve.

Table I shows the distribution of Illiac machine time for the month of December.

TABLE I

	Hrs:Min	
Scheduled Maintenance	80:18	
Unscheduled Maintenance	16:37	
Classes	8:18	
Drum Engineering	11:12	
Leapfrog	1:54	
Library Development	8:06	
R.A.R.	:10	
Wasted	:47	
		127:22

TABLE I
(cont'd.)

Use by Departments

	Hrs:Min
Aeronautical Engineering	:24
Agricultural Economics	1:26
Agronomy	15:09
Animal Science	1:28
Astronomy (Nonr 1834(22))	3:47
Astronomy (NSF G-5512)	:21
Bur. of Economic and Business Research	:11
Bureau of Educational Research (PH-M-1839)	1:13
Bureau of Educational Research	7:05
Chemistry (NSF G-7336)	3:58
Chemistry (Nonr 1834(13))	2:16
Chemistry (NSF G-5907)	:21
Chemistry	23:09
Coordinated Science Laboratory	54:10
Dairy Science	:05
Digital Computer Laboratory(AEC AT(11-1)415)	7:39
Digital Computer Laboratory (NSF G-9503)	11:14
Digital Computer Laboratory (Nonr 1834(27))	4:42
Digital Computer Laboratory	2:29
Economics (NSF G-7056)	6:27
Economics	:31
Electrical Engineering (AF 33(616)-6079)	:58
Electrical Engineering (NSF G-7421)	1:38
Electrical Engineering	7:21
Food Technology (Q.M. 1332)	:18
Food Technology	6:08
Geology	1:23
Institute for Res. on Except. Children	:17
Institute of Communications Research	2:23
Liberal Arts and Sciences	2:53
Mathematics	:21
Mechanical Engineering	5:59
Mining and Met. Engineering (AF 6770)	:12
Petroleum Engineering	:23
Physical Education	:05
Physics (Nonr 1834(12))	4:37
Physics (AF49 638 529)	:07
Physics	31:24
Psychology (Nonr 1834(11))	3:39
Psychology (M 1733)	13:52
Psychology (AF 49(638)-371)	4:53
Psychology (MD 2020)	2:38
Psychology (NIH M2331 ACT 7289)	:05
Psychology (1715)	3:03
Psychology (USPHSM 1041 R2)	:41
Psychology	38:20

TABLE I
(cont'd.)

Use by Departments

	Hrs:Min		
State Natural History Survey	:36		
Statistics	3:53		
Structural Research (NSF G-6572)	6:44		
Structural Research (IRH 46)	:06		
Structural Research	65:34		
Student Counseling	1:19		
Theor. and Applied Mech. (NOBS 72069)	:05		
Theor. and Applied Mechanics	1:56		
Veterinary Pathology (MD 728)	:13		
Veterinary Pathology	:20		
Water Survey (DA 36 039 SC 75055)	8:16		
Water Survey	:41		
Zoology	:14		
Purdue University	2:26		
Stanford Research Institute	7:35		
State of New Jersey	:36		
U. S. Navy	:56		
		383:13	
			510:35

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7 a.m. and 10:30 a.m. Since the periods between 7 a.m. and 10:30 a.m. together with certain irregular periods, such as Saturdays and Sundays, are devoted to a heterogeneous group of engineering, maintenance, and laboratory functions, it is more instructive, from an error standpoint, to look at the periods between 10:30 a.m. and 7 a.m. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use, although certain engineering procedures frequently require the scheduling of extra maintenance time. With this in mind, a summary table has been prepared using the period between 10:30 a.m. and 7 a.m. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to routine engineering, the amount of time devoted to repairs because of breakdowns, and a number of failures while the machine was listed as running. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test,

the length of time which it has been used on the machine is listed separately, together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that, except during scheduled engineering periods, any interruption of machine time that was not planned is considered a failure in this table. In rare cases, where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for December.

TABLE III

Memory		2
Arithmetic		3
Punch		1
Reader		12
Scope		2
Drum		8
Unknown		9
	Total	37

TABLE II

DATE	RUNNING OK TIME	REPAIR TIME	SCHEDULED ENGINEERING	INTERRUPTIONS OR FAILURES STOPPING OK TIME	TYPES OF INTERRUPTIONS OR FAILURES CAUSING REPAIR TIME	WASTED	LEAPFROG	FAILURES STOPPING LEAPFROG
12/1/59	21:13	:00	2:47	0		0	:00	0
12/2/59	20:23	:02	3:35	2	(1) Punch error (2) Unknown	0	:00	0
12/3/59	21:07	:01	2:52	1	(1) Unknown	0	:00	0
12/4/59	20:06	:01	3:53	1	(1) Drum failure	0	:00	0
12/7/59	19:56	:04	4:00	4	(1) Unknown (2,3,4) Reader "B" error	0	:00	0
12/8/59	21:36	:01	2:23	1	(1) Reader "B" error	0	:00	0
12/9/59	20:08	:01	3:51	1	(1) Reader "B" error	0	:00	0
12/10/59	20:15	:00	3:45	0		0	:00	0
12/11/59	14:38	5:22	4:00	3	(1) Drum failure (2) Memory failure 2^{-28} (3) Unknown	0	:00	0
12/14/59	20:02	:07	3:51	7	(1) Unknown (2,3,4,5,6,7) Reader "B" error	0	:39	0
12/15/59	10:32	9:28	4:00	3	(1) Adder error (2,3) Drum Failure	0	:00	0
12/16/59	18:19	1:48	3:53	3	(1,2,3) Drum	0	:00	0
12/17/59	20:03	:02	3:55	2	(1,2) Unknown	0	:00	0
12/18/59	20:59	:01	3:00	1	(1) Tape tore in reader "D"	0	:00	0
12/21/59	20:43	:00	3:17	0		0	:00	0
12/22/59	19:24	:36	4:00	1	(1) Illiac failure, address gate	0	:00	0
12/23/59	19:30	:30	4:00	1	(1) Illiac error	0	:00	0
12/24/59	4:00	:00	:00	0		0	:00	0
12/18/59	20:42	:01	3:17	1	(1) Unknown	0	:00	0
12/29/59	18:45	1:21	3:54	1	(1) Memory 2^{-30}	0	:00	0
12/30/59	20:00	:29	3:31	1	(1) Scope failure	0	:00	0
12/31/59	16:57	2:04	2:59	3	(1) Unknown (2) Scope failure (3) Drum failure	0	:00	0
TOTALS	409:18	21:59	74:43	37		0	:39	0

IBM 650 USE AND OPERATION

New IBM 650 Codes

During the month of December one 650 routine was revised and one new routine was added to the IBM 650 Library.

Revised K2' - 56' Correlations, Regression Coefficients, Means and Standard Deviations. This routine is a revised version of K2'-56' which was previously published. The revised version contains a more adequate description of procedures for use of the routine. The routine will calculate up to 10 columns of a matrix of correlations where the number of variables may be as large as 120. Also computed are means, standard deviations, corrected sums of squares, corrected sums of cross products, and regression coefficients.

(L. Matsunaga)

P7' - 59' Memory Dump on the 407 with Zero Deletion and Control Card Entry. This routine is intended for post mortem dumping of the non-zero portion of either the drum or the fast core storage. It is more versatile than previous routines in that selected regions to be dumped may be chosen by means of control cards.

(R. Flenner and M. Gray)

IBM 650 Usage

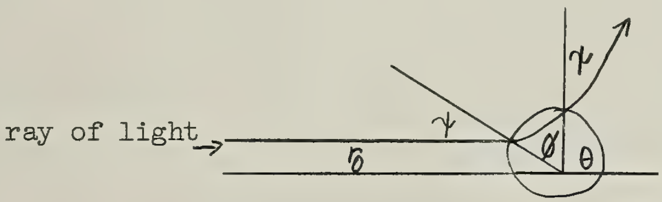
During the month of December specifications were presented for 9 new problems. This list does not indicate how the IBM 650 was used because large amounts of machine time may have been consumed by problems with numbers less than 63'T. Numbers followed by T are for theses.

63' T Chemistry. Structural Determination of $BaS_2O_3.H_2O$. The program is the structural determination of single crystals of $BaS_2O_3.H_2O$ via X-ray diffraction techniques. The raw intensity data obtained from the exposure of crystals to X-rays and registration upon film requires many routine corrections. This program is an extension and a plotting of the data obtained from an earlier problem, 62' T, submitted to this Laboratory.

64' Marketing. Consumer Advertising Recognition. This is a Marketing Class problem classified as departmental research. The one-column frequency distribution tables will give counts and percentages of answers on a marketing survey to be used in an analysis of the survey. The survey covered a group of 425 people -- each questionnaire contains 50 questions concerning candy bar consumption in relation to advertising comprehension.

Preliminary examination of the frequency tables produced in this run will be made to set up further analyses and cross tabulations.

65' Physics. Scattering Angle. In the calculation of scattering of light by a bubble of hydrogen immersed in liquid hydrogen, the intensity is a function of the angle ψ where ψ is defined as follows:



The intensity is found to be = $r_0^2\ \bar{T}^2\ G$, where r_0^2 will not enter into this 650 program; and

$$\bar{T}^2 = \frac{1}{2}\left[\left(1 - \frac{\sin^2(\phi - \psi)}{\sin^2(\phi + \psi)}\right)^2 + \left(1 - \frac{\tan^2(\phi - \psi)}{\tan^2(\phi + \psi)}\right)^2\right]$$

and

$$G = \frac{\sin\ \psi\ \cos\ \psi\ n\ \cos\ \psi}{Z\ \sin\ \theta\ (n\ \cos\psi - \cos\ \phi)}$$

where

N = relative index of refraction for bubble.

The expression for ϕ in terms of $\psi \equiv \sin\ \phi = n\ \sin\ \psi$, so that $n\ \sin\psi < 1$ or $\psi < \sin^{-1}(\frac{1}{n})$. ψ_i, $\Delta\psi$, ψ_F and N are read into the 650; and ψ, θ, G, $\bar{T}^2$, and G x $\bar{T}^2$ are printed out for the various angles ψ up to and including ψ_F in steps at $\Delta\psi$.

66' Education. Reading of Science Materials. Factors Associated With Ability of Sixth-Grade Children to Read Science Materials for Each of Two Predetermined Purposes. The problem is to discover relationships between reading speeds and comprehensions when reading scientific materials in order to get the main idea of the passage and in order to keep in mind the sequential ideas presented. Variables are age, non-verbal intelligence, general reading abilities, ability to read science, and academic achievement in science. Total sample size is 46 students. All variables will be correlated against science reading abilities with the two specified purposes. In addition, certain of the variables will be correlated against each other.

67' T Botany. Factors Effecting Occurrence of Symptomless Wound-Tumor Sweet Clover. The research problem involves the analysis of the effect of varied heat treatments on the occurrence of symptomless plants derived from plants diseased with Wound-tumor. Using the Probit-III analysis program it will be possible to determine the slope of the rate of inactivation (for each treatment), the relative heterogeniety of the samples used in each experiment, and the chi squares for the various experiments.

68' Animal Science. Influence of Management Practices on Pork Quality. Simple correlation coefficients are needed for 24 criteria in which there are missing data. This research constitutes studies on more than 100 swine and on the pork products produced. The data are the result of physiological studies on living swine and of physical, histological and chemical studies of muscle tissue.

69' Chemistry. Helium Atom Energy. This problem involves the quantum mechanical description of the ground electronic state of the helium atom. Essentially, the computer is used to compute numerical values for the atomic integrals; the integrals are combined to form the matrix elements and a secular equation is solved for the lowest eigenvalue and the corresponding eigenvectors.

70' T Psychology. Regularity and length of intertrial intervals in the extinction of a fear response. This is a 3 x 3 factorial design with ten subjects in each cell. For each subject there are two sets of eleven measures each. The measures represent time scores on successive extinction trials.

The problem is to find out how each of the eleven measures in a set correlates with each of the other ten measures when the correlation is computed across all subjects. In addition, correlations in various subgroups of the ninety subjects will be found.

Previous investigators (Reynolds, B., J. Exp. Psychol., 1952, 43, 341-348; Zeaman, D., and Kaufman, H., Psychol. Monog., 1955, 69, No. 391), have reported that in learning situations:

1) the correlations between successive trials become greater with further training;
2) the correlations between trials decrease with an increase in the amount of practice separating them;
3) the correlations between initial trials and later trials are greater when the trials are spaced than when they are massed.

The object of this program is to see if these findings can be extended to an extinction situation.

71' Marketing. Consumer Advertising Recognition. Students in the marketing research class have made preliminary analyses of the frequency counts of data obtained from each question on the questionnaires in our study. These frequency counts were obtained by use of the IBM 650 as described in Problem 64'.

From these preliminary analyses it is evident that several relationships may exist among the data which, if examined, would indicate to what extent consumer recognition of the advertising under study is related to selected socio-economic characteristics of consumers and certain measures of consumer behavior. In order to examine these relationships cross tabulations of several selected questions are needed.

These data are being analyzed by 8 committees of students in this marketing research class. Each committee makes its own analysis and requests the additional cross tabulations it believes it needs to complete the analysis. Any duplication among the requests is eliminated.

Table I' shows the distribution of the IBM 650 machine time for the month of December.

TABLE I'

	Hrs:Min		
Scheduled Maintenance	20:06		
Unscheduled Maintenance	17:11		
Air Conditioning	2:35		
Library Development by DCL	16:17		
Library Development by SSU	1:25		
Log Summation	:58		
Wasted	42:16		
		100:48	
Use by Departments			
Agronomy	:15		
Botany	:52		
Chemistry	3:41		
Civil Engineering 297 - 497	2:48		
Mathematics 295	2:35		
Mathematics 395	16:25		
Physics	1:09		
Psychology	1:02		
Statistical Service Unit	59:45		
Structural Research	2:44		
Theoretical and Applied Mechanics	3:08		
		94:24	
			195:12

Error Frequency and Analysis

The IBM 650 is normally on from 8 a.m. to 5 p.m. The machine is used for preventive maintenance from 8 a.m. to 12 noon on Wednesdays.

Table II' gives the daily breakdown of machine time with respect to wastage and unscheduled maintenance.

Table III' presents a summary of errors for December.

TABLE III'

Bad tube in 650	1
Tape Units	10
407	2
Floating Point	3
Main Circuit Breaker	1
533	2
Air Conditioning	1
Operator Error	1
Total	21

TABLE II'

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
12/1/59	7:33			1:27	0		
12/2/59	2:46	4:02		2:12	0		
12/3/59	7:59		1:15	:07	4		(1) Blank accumulators - bad ckt. tube (2-4) Tape units read incorrectly
12/4/59	7:03			1:57	0		
12/7/59	5:33		2:40	:47	1		407 not printing correctly
12/8/59	4:19			4:41	3		(1-3) Blank and double bits in accumulator. Floating point
12/9/59	:25	4:09	4:26		0		Repair time for 12/8 floating point trouble.
12/10/59	5:57		2:23	:40	0		Repair time for floating point trouble
12/11/59	4:28			4:32	0		
12/14/59	2:58			6:17	0		
12/15/59	8:17			:43	0		
12/16/59	2:27	3:52	3:01	:00	1		Repair time for main circuit breaker.
12/17/59	8:33			:27	0		
12/18/59	4:11		:58	3:51	1		Tape unit not reading properly
12/21/59	3:19		1:53	1:13	1	2:35	Bad relay and 2 bad lights in unit 2
12/22/59	6:05		:25	3:00	2		(1-2) Blank bits. Replaced wire.
12/23/59	4:47	4:05		:08	3		(1) Tape unit. (2) Reading errors. (3) Signs dropped from information read from tape.
12/24/59	3:05		:10	:45	1		Operator error.
12/28/59	6:58			2:16	1		Fuse blew on 407

TABLE II' (Cont'd.)

DATE	RUNNING OK TIME	SCHEDULED ENGINEERING	REPAIR TIME	WASTED	FAILURES STOPPING OK TIME	AIR CONDI-TIONING	TYPES OF FAILURES CAUSING REPAIR TIME
12/29/59	4:59			4:01	0		
12/30/59	5:10	3:58		:24	3		(1) Read error on tape unit 1. (2-3) Failure to write tape on tape unit 2.
12/31/59	6:12			2:48	0		
TOTALS	113:04	20:06	17:11	42:16	21	2:35	

PART VI

GENERAL LABORATORY INFORMATION

Seminars

"The Use of Variable Capacity Diodes in Digital Circuits", by Dr. Arthur Lo, Research Engineer, RCA Laboratories, Princeton, New Jersey, December 7, 1959.

"The Stability of Solutions to a Class of Ordinary Differential Equations", by Professor James H. Bartlett, Department of Physics, University of Illinois, Urbana, Illinois, December 14, 1959.

Reports

Report No. 95, "Numerical Quadrature Over a Rectangular Domain in Two or More Dimensions", by Dr. J. C. P. Miller, Visiting Professor, University Mathematical Laboratory, Cambridge, England, December 11, 1959.

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